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Fraser et al.

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(54) **NON-CONTINUOUSLY LAMINATED MULTI-LAYERED BAGS**

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(73) Assignee: **The Glad Products Company**, Oakland, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/516,417**

(22) Filed: **Oct. 16, 2014**

(65) **Prior Publication Data**

US 2015/0036951 A1 Feb. 5, 2015

**Related U.S. Application Data**

(60) Division of application No. 13/273,384, filed on Oct. 14, 2011, now Pat. No. 8,888,365, which is a (Continued)

(51) **Int. Cl.**
***B65D 30/08*** (2006.01)
***B29C 55/06*** (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .............. ***B65D 31/02*** (2013.01); ***B29C 55/04*** (2013.01); ***B29C 55/06*** (2013.01); ***B29C 55/08*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ........ B32B 2038/0028; B32B 37/0076; B32B 7/045; B32B 7/14; B32B 2307/514;
(Continued)

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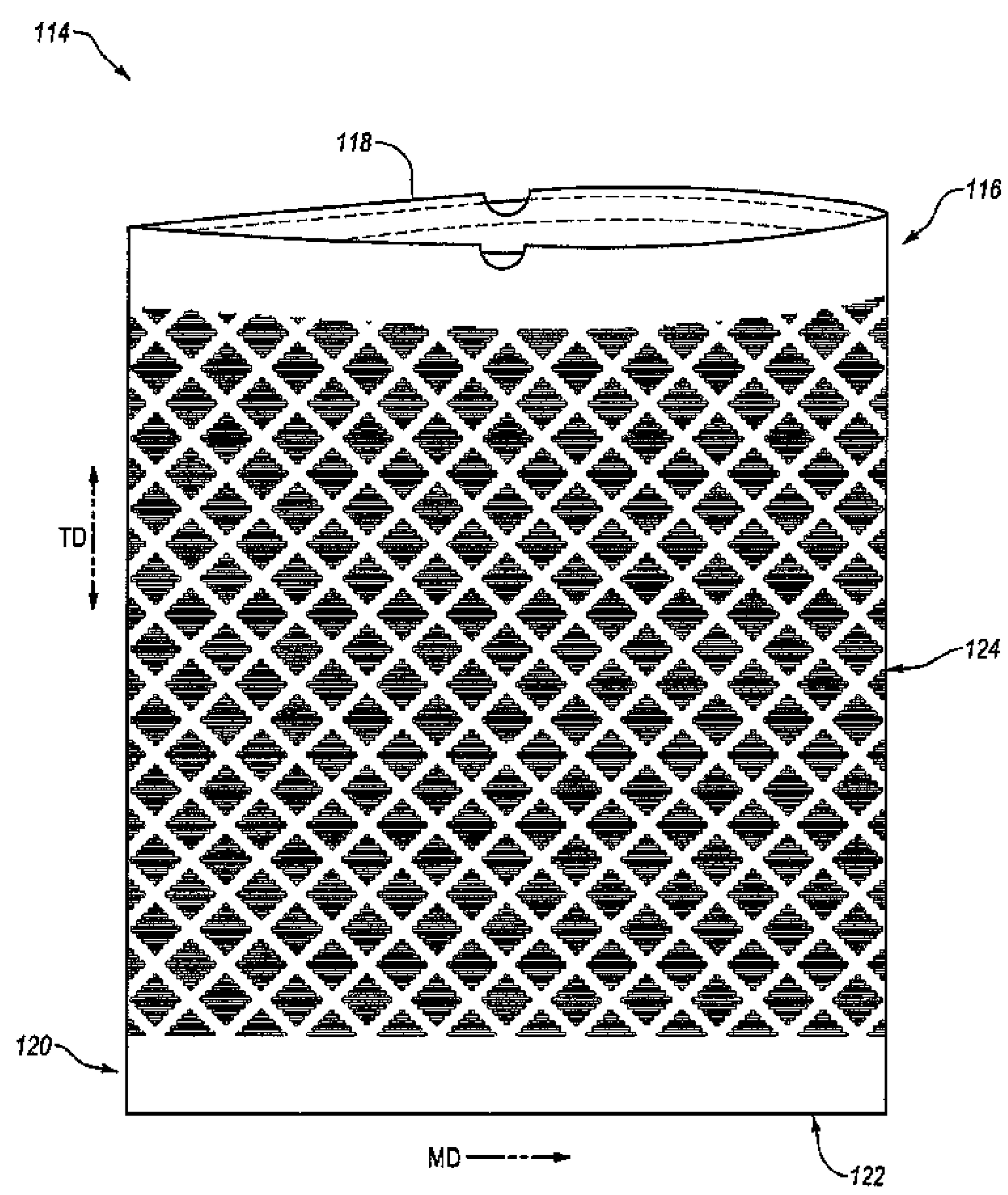
*Assistant Examiner* — Jimmy R. Smith, Jr.
(74) *Attorney, Agent, or Firm* — Thomas C. Feix

(57) **ABSTRACT**

Multi-layer bags may be formed to include first and second sidewalls joined along a first side edge, an opposite second side edge, and a closed bottom edge. The first and second layers may be non-continuously laminated together to include bonded regions in which the layers are bonded and unbonded regions in which the layers are not bonded. Such a bag may be described as a “bag-in-a-bag” type configuration in which the inner bag is non-continuously bonded to the outer bag. The inventors have surprisingly found that such configurations of non-continuous bonding provides increased and unexpected strength properties to the multi-layer films and bags.

**14 Claims, 27 Drawing Sheets**



**Related U.S. Application Data**

continuation-in-part of application No. 12/947,025, filed on Nov. 16, 2010, now Pat. No. 8,603,609.

(60) Provisional application No. 61/261,673, filed on Nov. 16, 2009.

(51) **Int. Cl.**

| | |
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| ***B29C 55/08*** | (2006.01) |
| ***B29C 55/04*** | (2006.01) |
| ***B32B 27/08*** | (2006.01) |
| ***B32B 27/32*** | (2006.01) |
| ***B32B 7/02*** | (2006.01) |
| ***B32B 7/04*** | (2006.01) |
| ***B32B 7/14*** | (2006.01) |
| ***B32B 37/00*** | (2006.01) |
| ***B32B 38/06*** | (2006.01) |
| ***B29C 65/56*** | (2006.01) |
| ***B29C 65/00*** | (2006.01) |
| ***B29C 65/48*** | (2006.01) |
| ***B31F 1/07*** | (2006.01) |
| ***B32B 27/30*** | (2006.01) |
| ***B32B 3/28*** | (2006.01) |
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| *B29L 31/00* | (2006.01) |
| *B29C 65/08* | (2006.01) |
| *B29C 65/18* | (2006.01) |
| *B29C 65/74* | (2006.01) |
| *B29C 65/02* | (2006.01) |
| *B31B 160/10* | (2017.01) |
| *B31B 155/00* | (2017.01) |
| *B31B 70/81* | (2017.01) |
| *B31B 70/94* | (2017.01) |
| *B31B 170/20* | (2017.01) |

(52) **U.S. Cl.**

CPC .............. ***B29C 65/48*** (2013.01); ***B29C 65/56*** (2013.01); ***B29C 66/1122*** (2013.01); ***B29C 66/232*** (2013.01); ***B29C 66/234*** (2013.01); ***B29C 66/3452*** (2013.01); ***B29C 66/43*** (2013.01); ***B29C 66/431*** (2013.01); ***B29C 66/438*** (2013.01); ***B29C 66/723*** (2013.01); ***B29C 66/73921*** (2013.01); ***B29C 66/81433*** (2013.01); ***B29C 66/81435*** (2013.01); ***B29C 66/83413*** (2013.01); ***B29C 66/8511*** (2013.01); ***B31F 1/07*** (2013.01); ***B32B 3/28*** (2013.01); ***B32B 7/02*** (2013.01); ***B32B 7/045*** (2013.01); ***B32B 7/14*** (2013.01); ***B32B 27/08*** (2013.01); ***B32B 27/306*** (2013.01); ***B32B 27/308*** (2013.01); ***B32B 27/32*** (2013.01); ***B32B 37/0076*** (2013.01); ***B32B 38/06*** (2013.01); *B29C 65/02* (2013.01); *B29C 65/08* (2013.01); *B29C 65/18* (2013.01); *B29C 65/743* (2013.01); *B29C 66/028* (2013.01); *B29C 66/436* (2013.01); *B29C 66/45* (2013.01); *B29C 66/71* (2013.01); *B29L 2031/7129* (2013.01); *B31B 70/8137* (2017.08); *B31B 70/942* (2017.08); *B31B 2155/00* (2017.08); *B31B 2155/0014* (2017.08); *B31B 2160/10* (2017.08); *B31B 2170/20* (2017.08); *B31F 2201/0764* (2013.01); *B32B 2038/0028* (2013.01); *B32B 2307/514* (2013.01); *B32B 2307/546* (2013.01); *B32B 2307/5825* (2013.01); *B32B 2307/7163* (2013.01); *B32B 2439/00* (2013.01); *B32B 2439/06* (2013.01); *Y10T 156/1051* (2015.01)

(58) **Field of Classification Search**

CPC ..... B32B 2439/06; B65D 31/02; B29C 66/43; B29C 55/04; B29C 55/06; B29C 55/08; B29L 2031/7129

USPC ............................ 264/290.2, 177.17, 211.12

See application file for complete search history.

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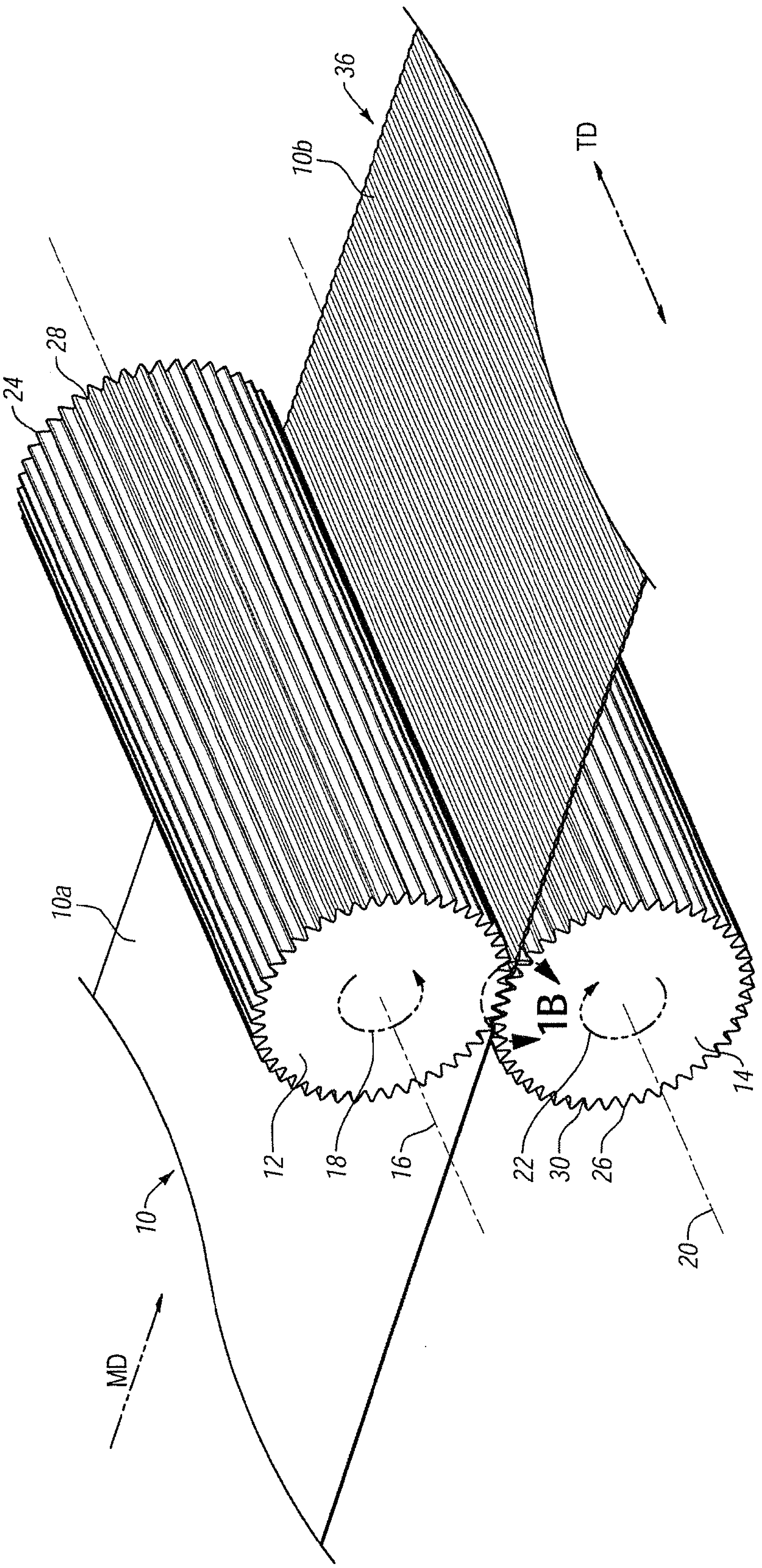


Fig. 1A

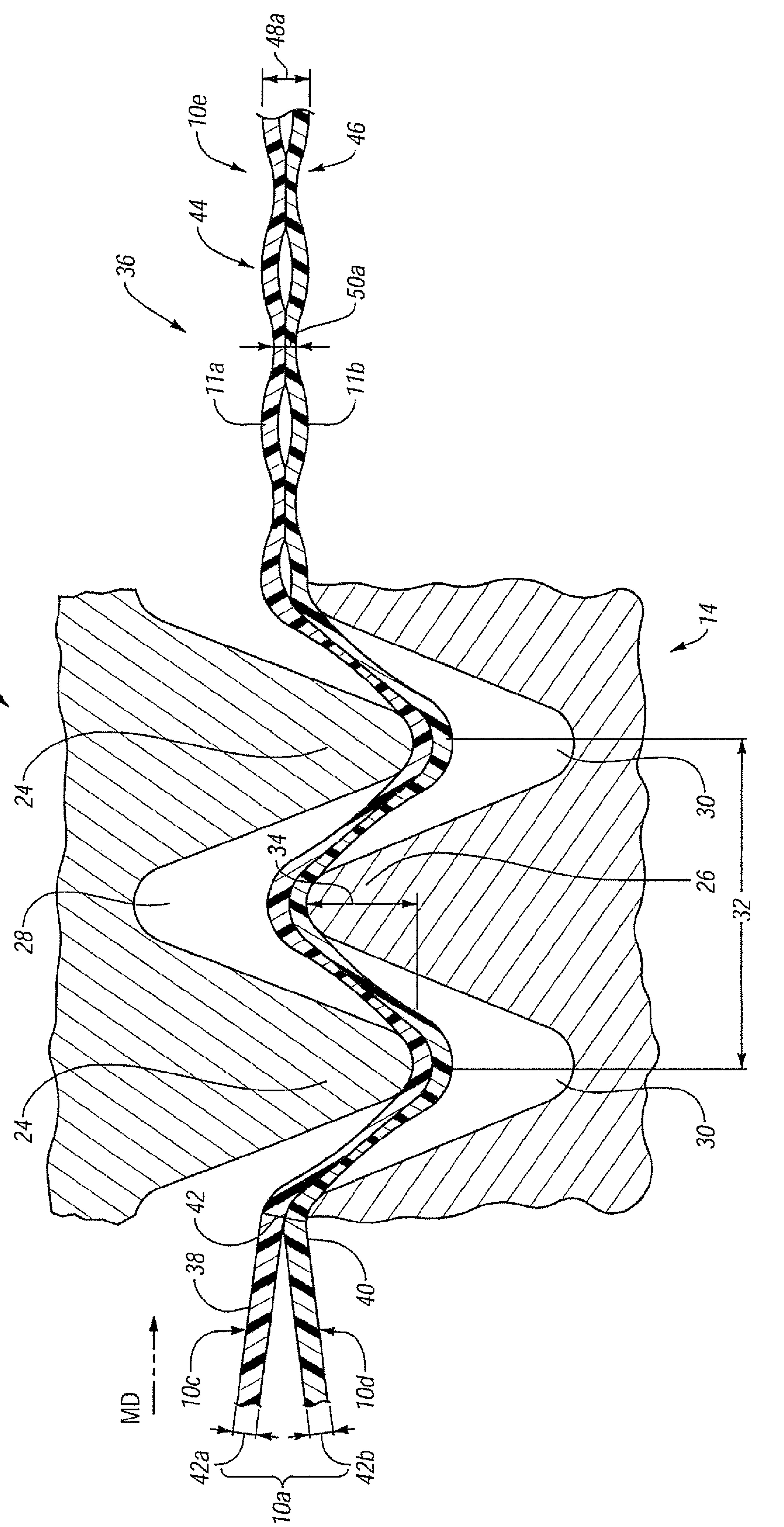
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Fig. 1B

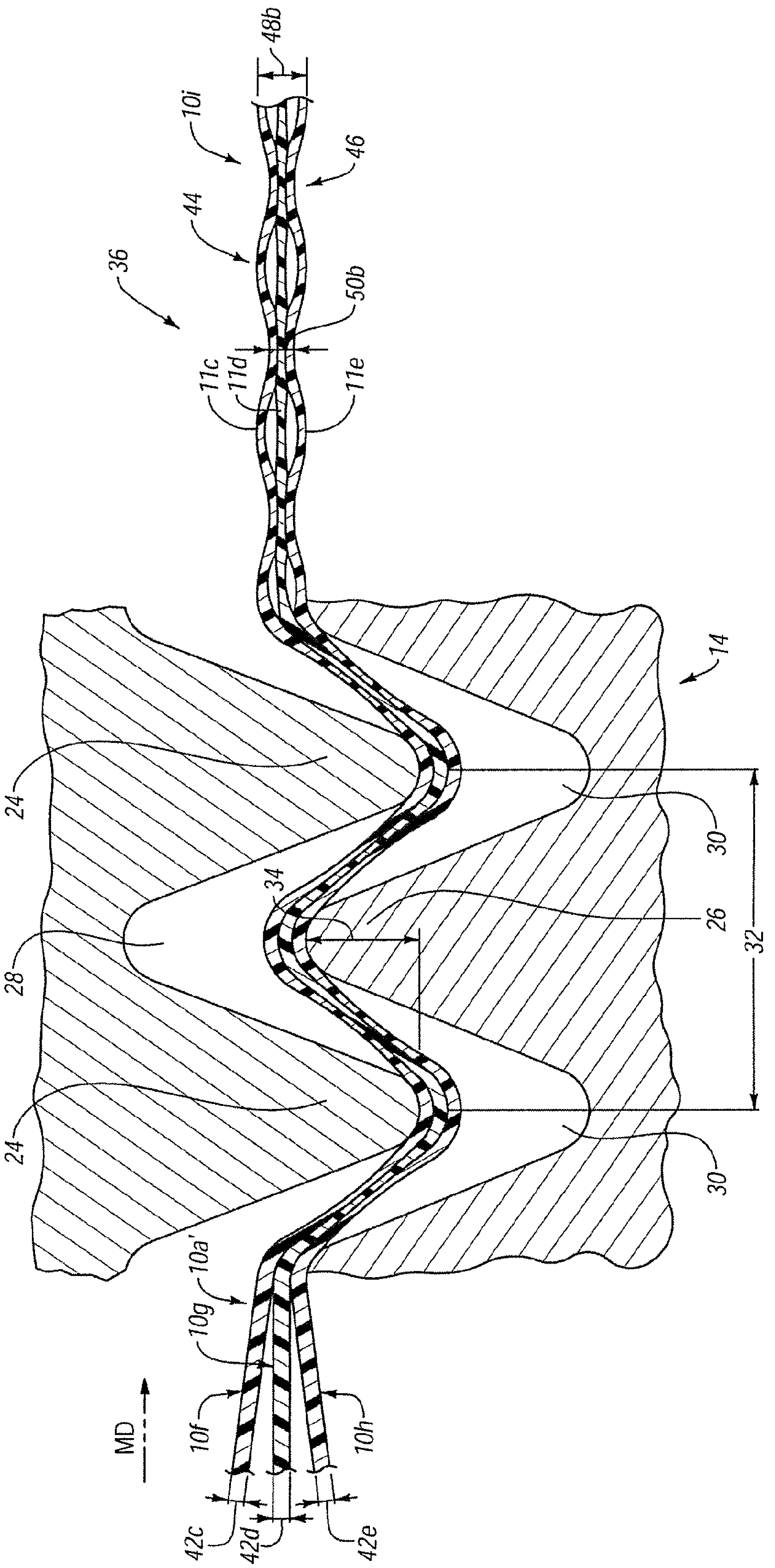
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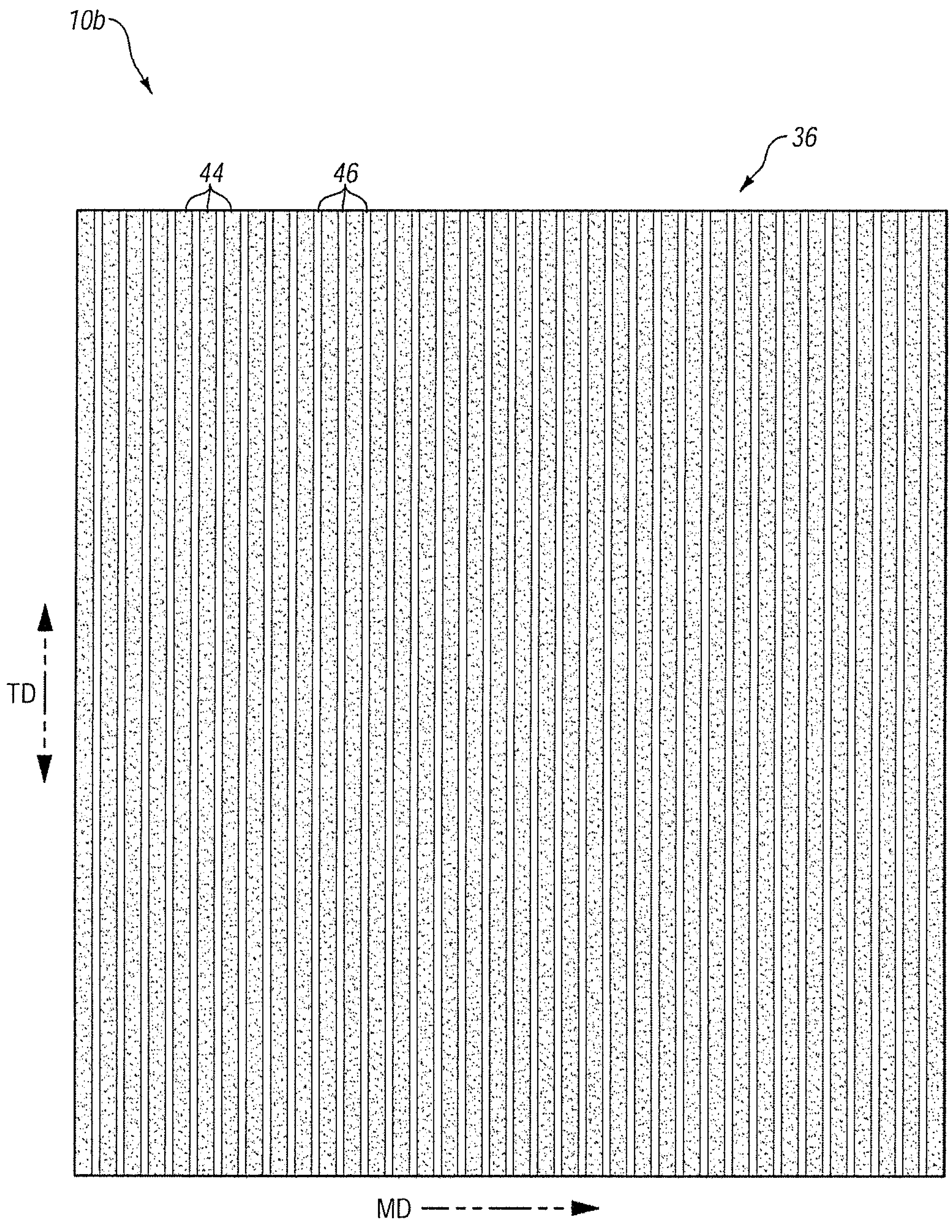
Fig. 1C

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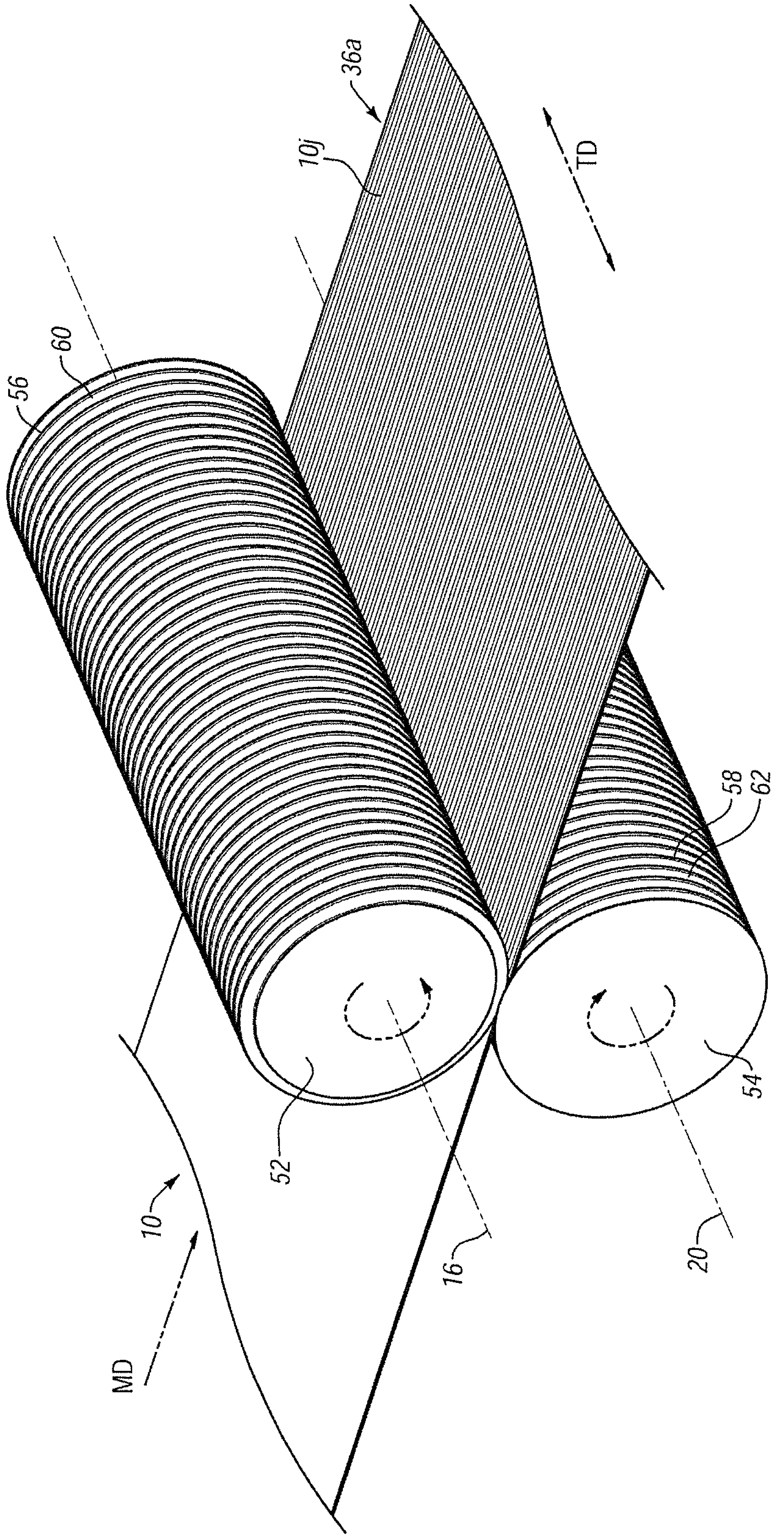


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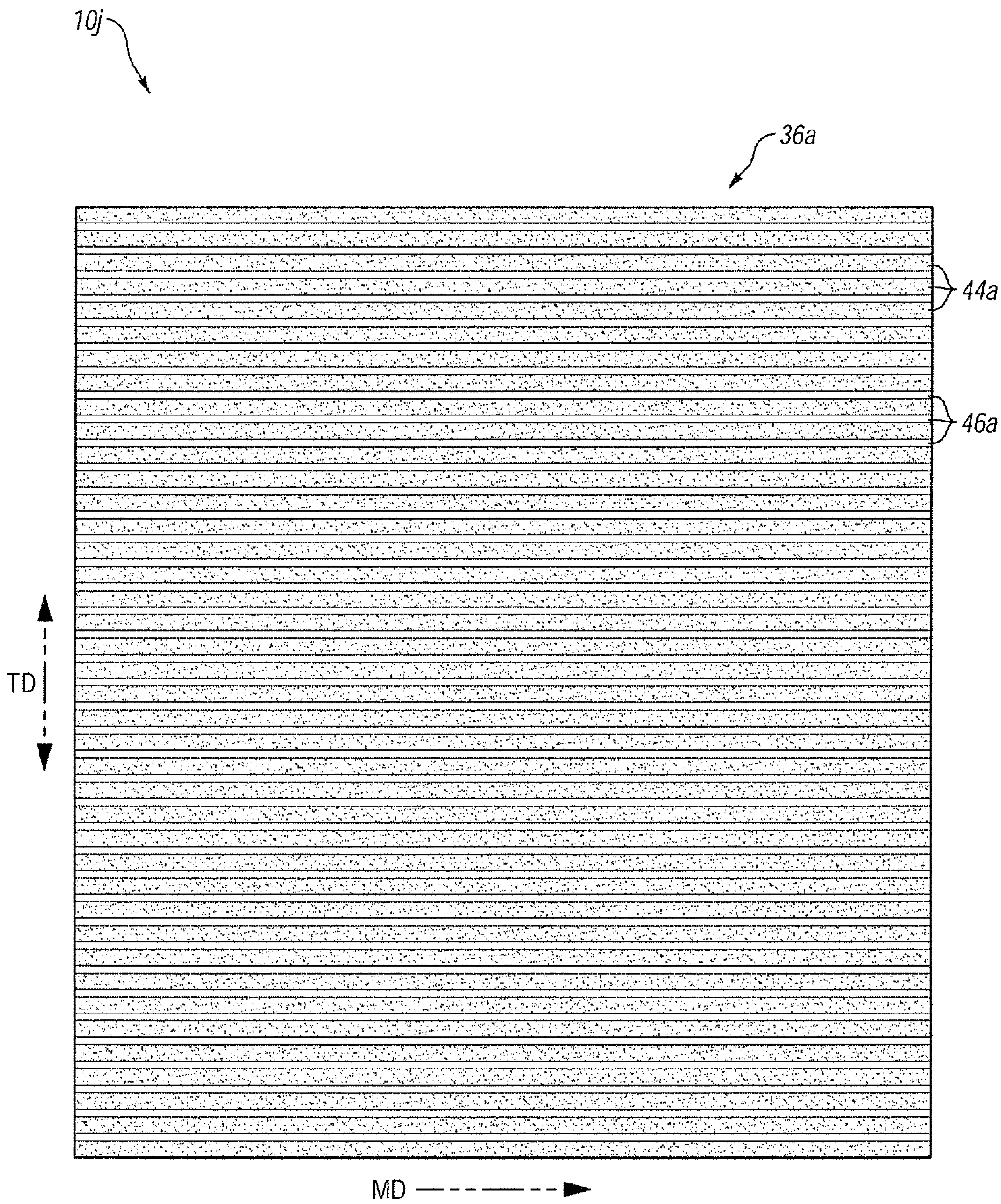


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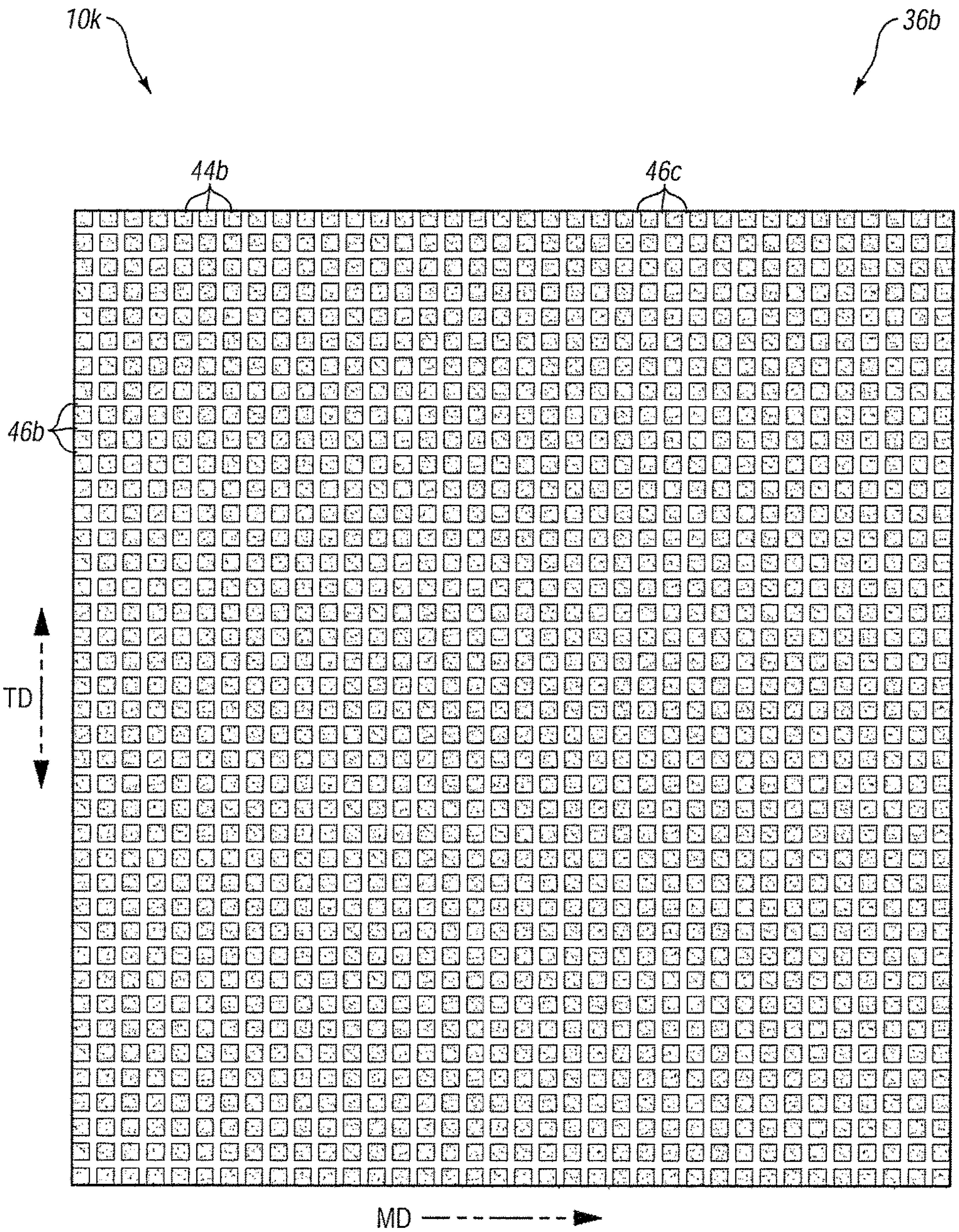


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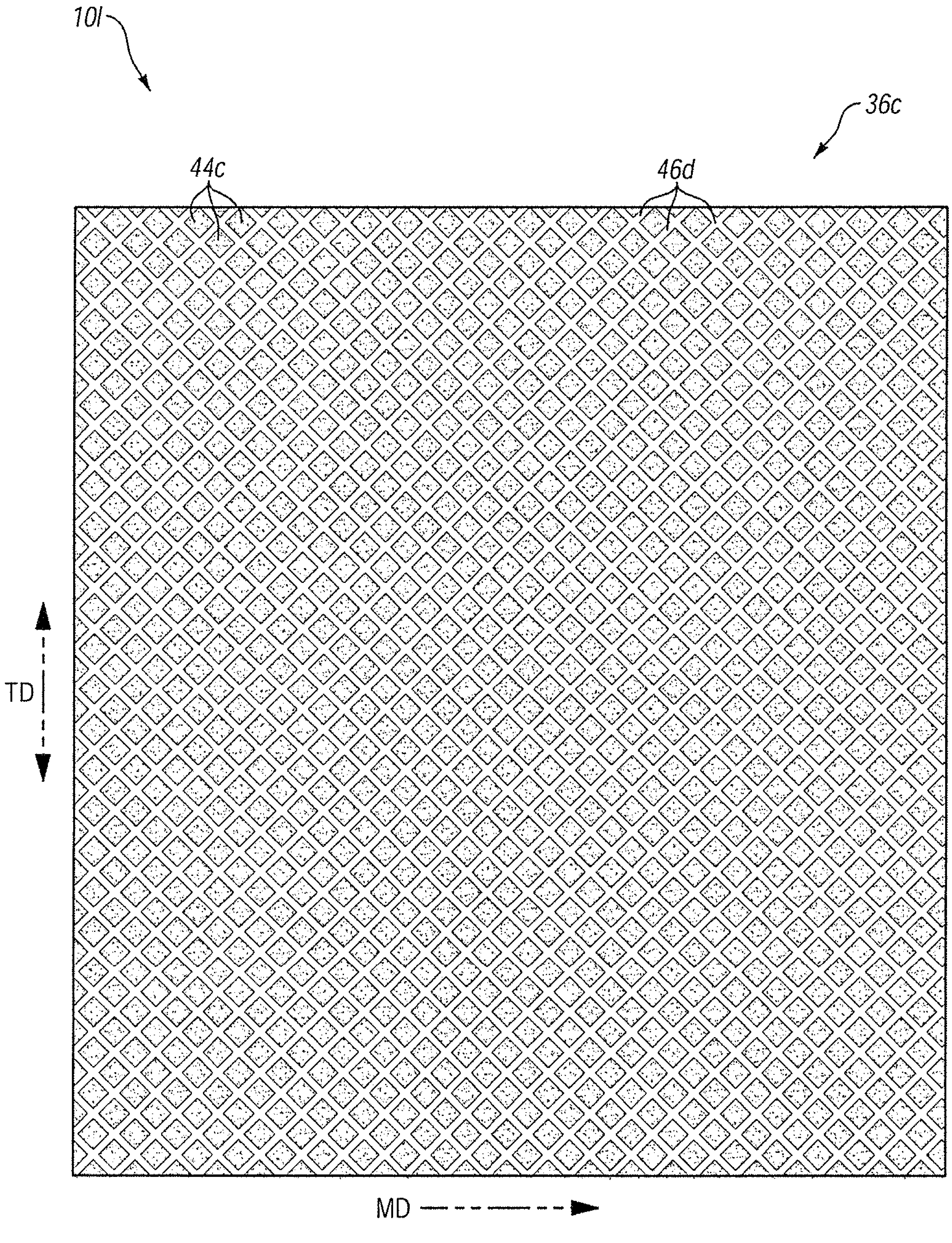


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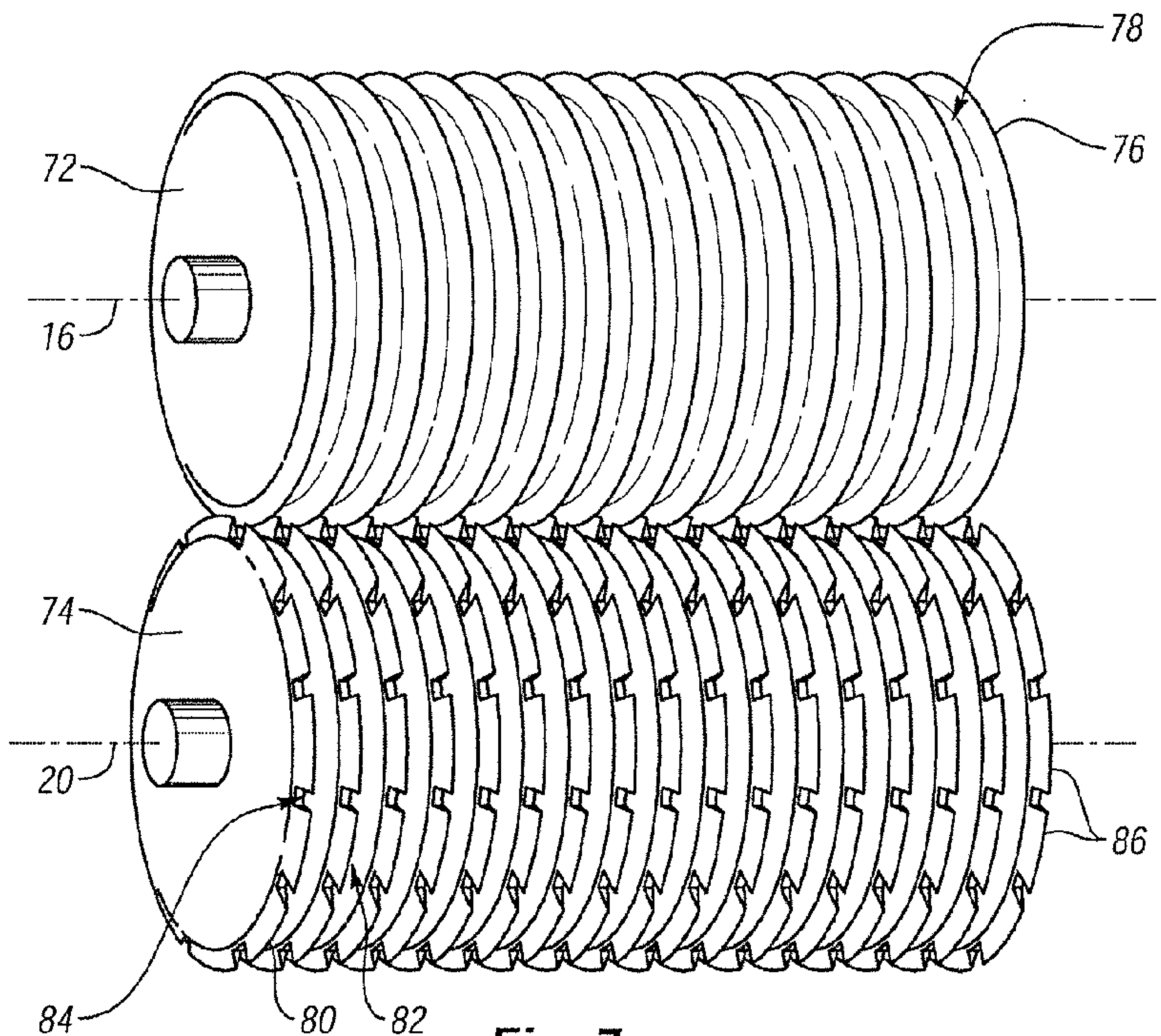
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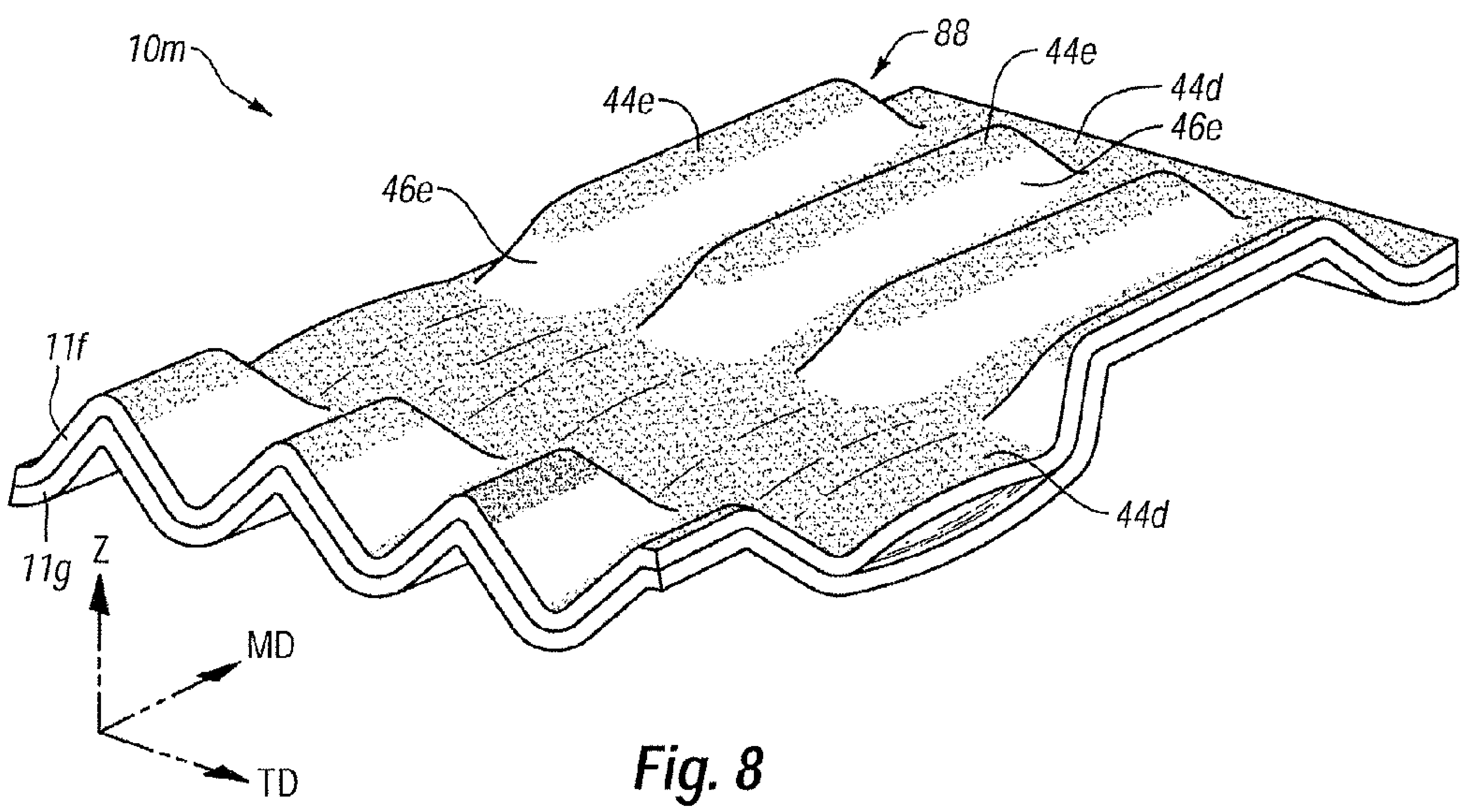
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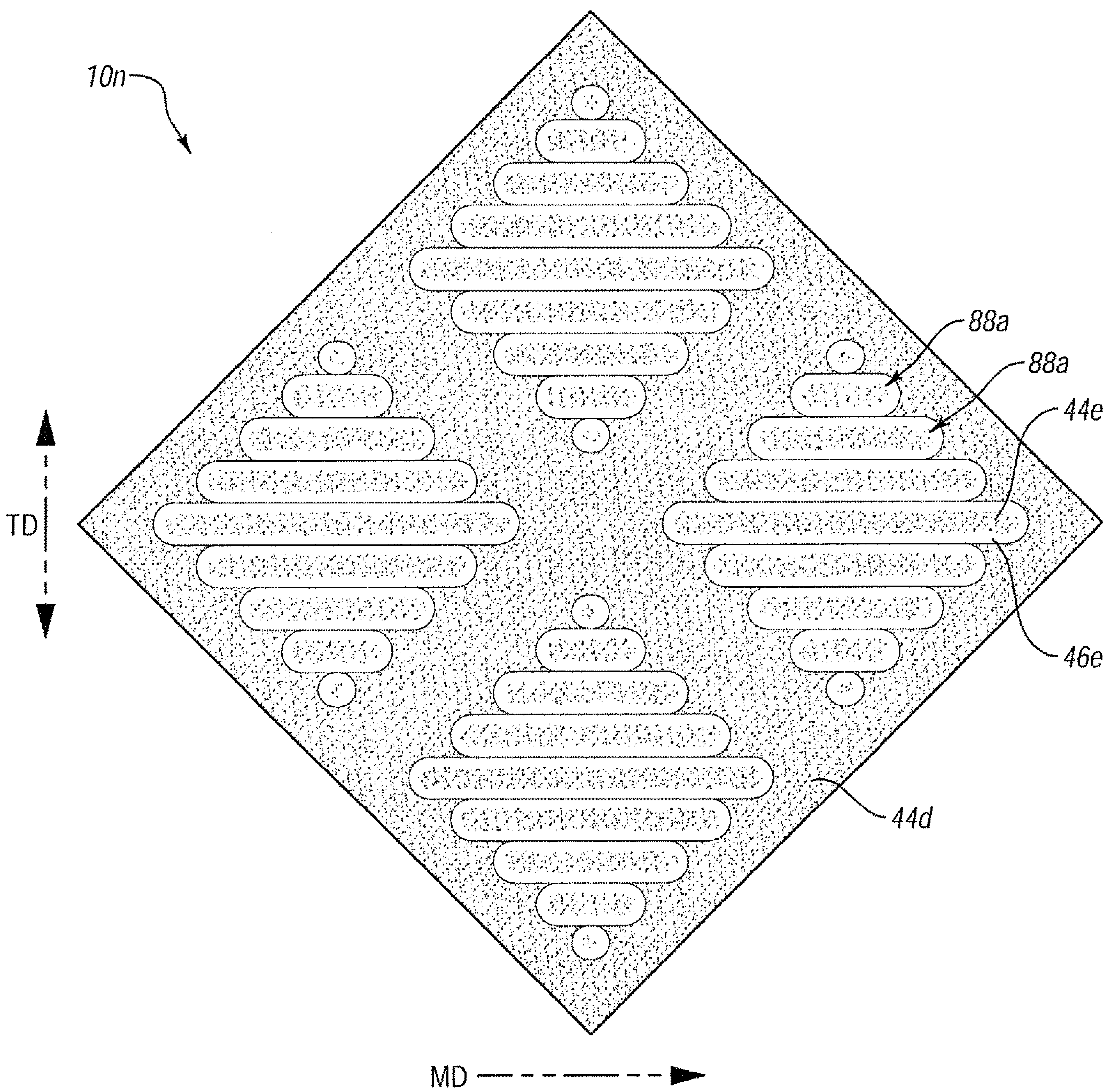


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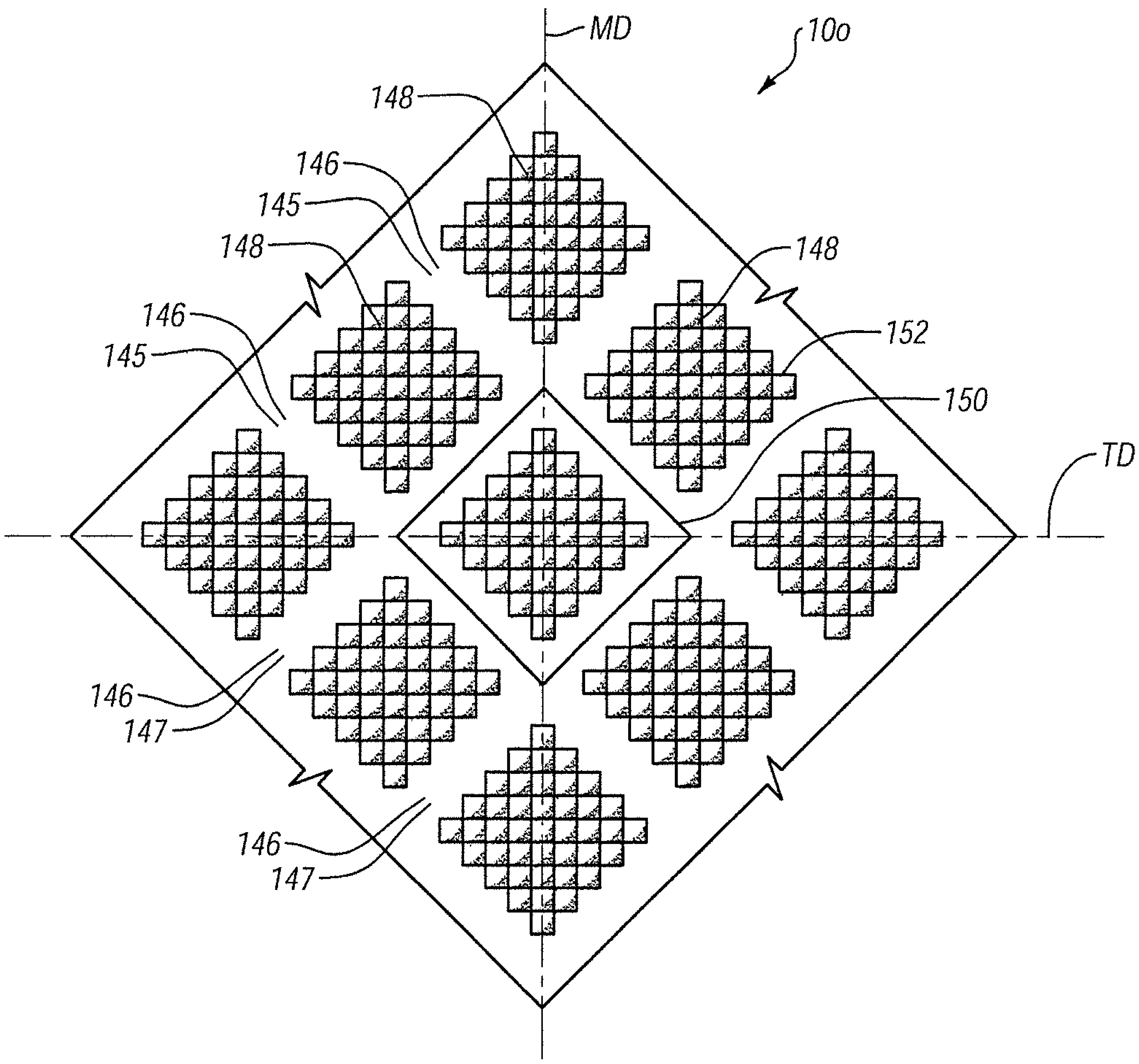
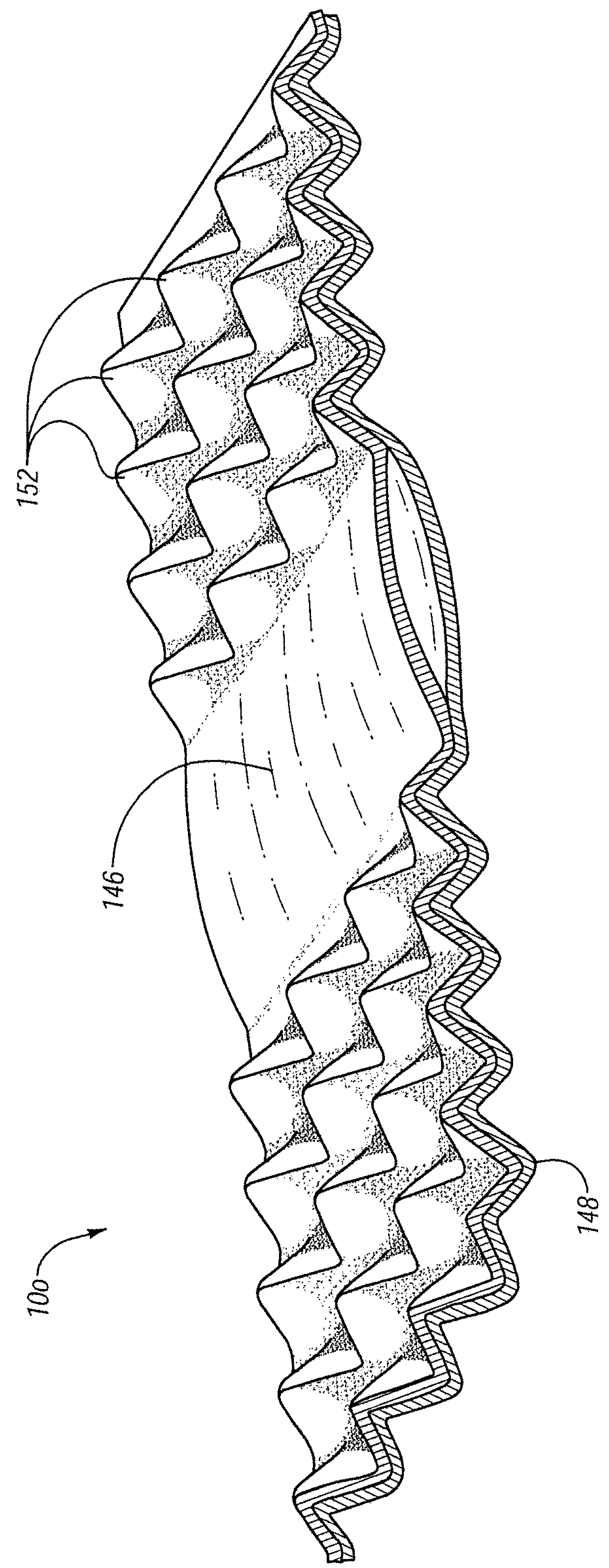



Fig. 10A

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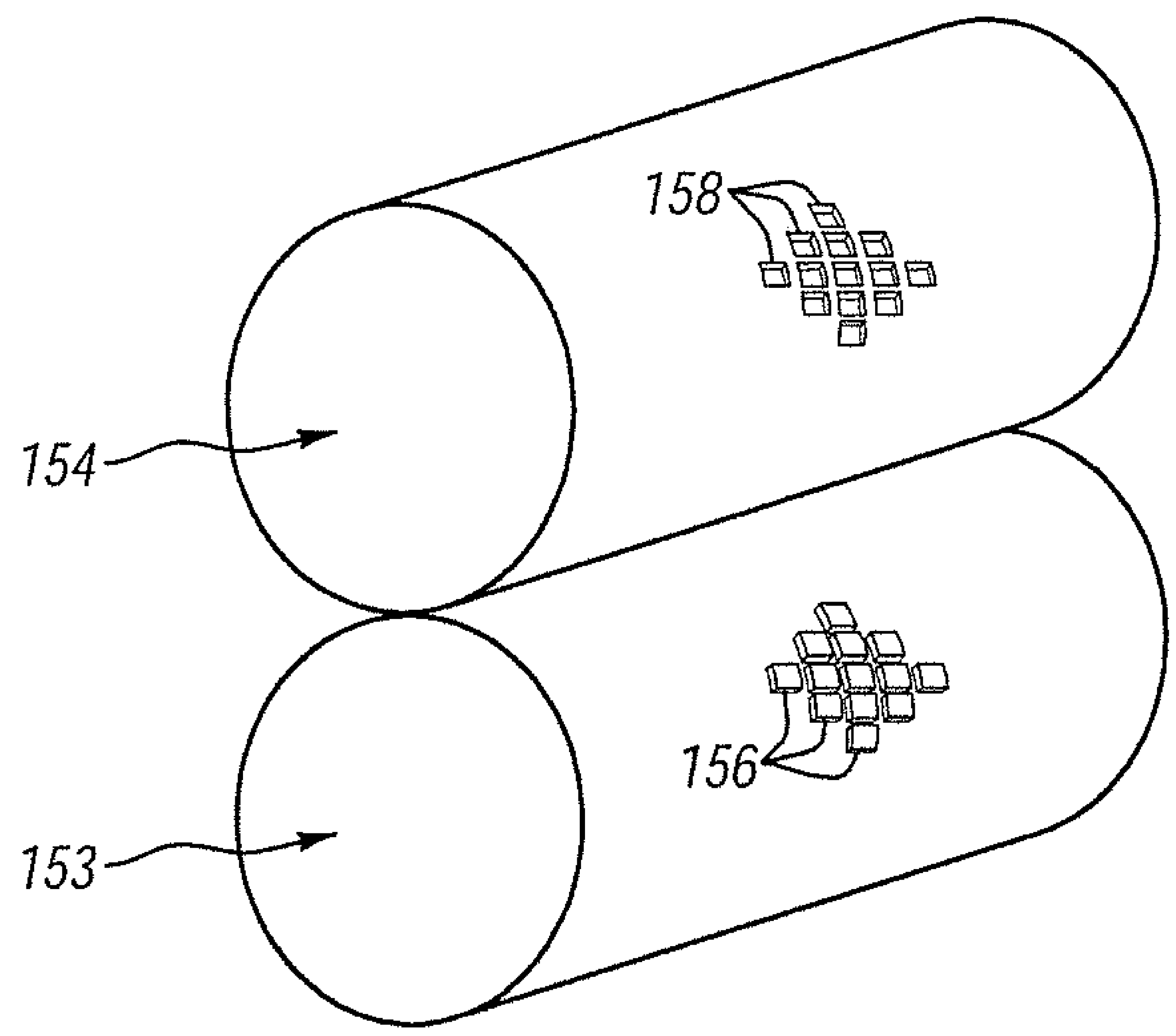
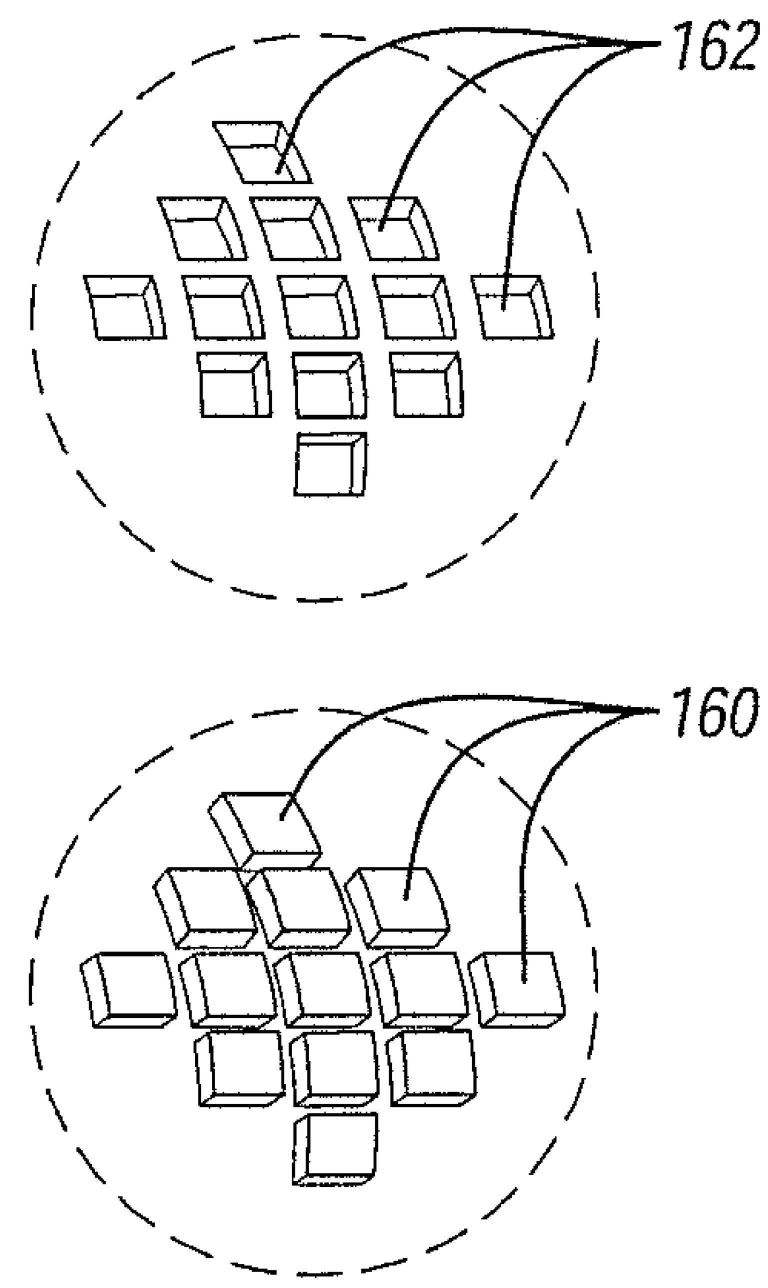



Fig. 11A

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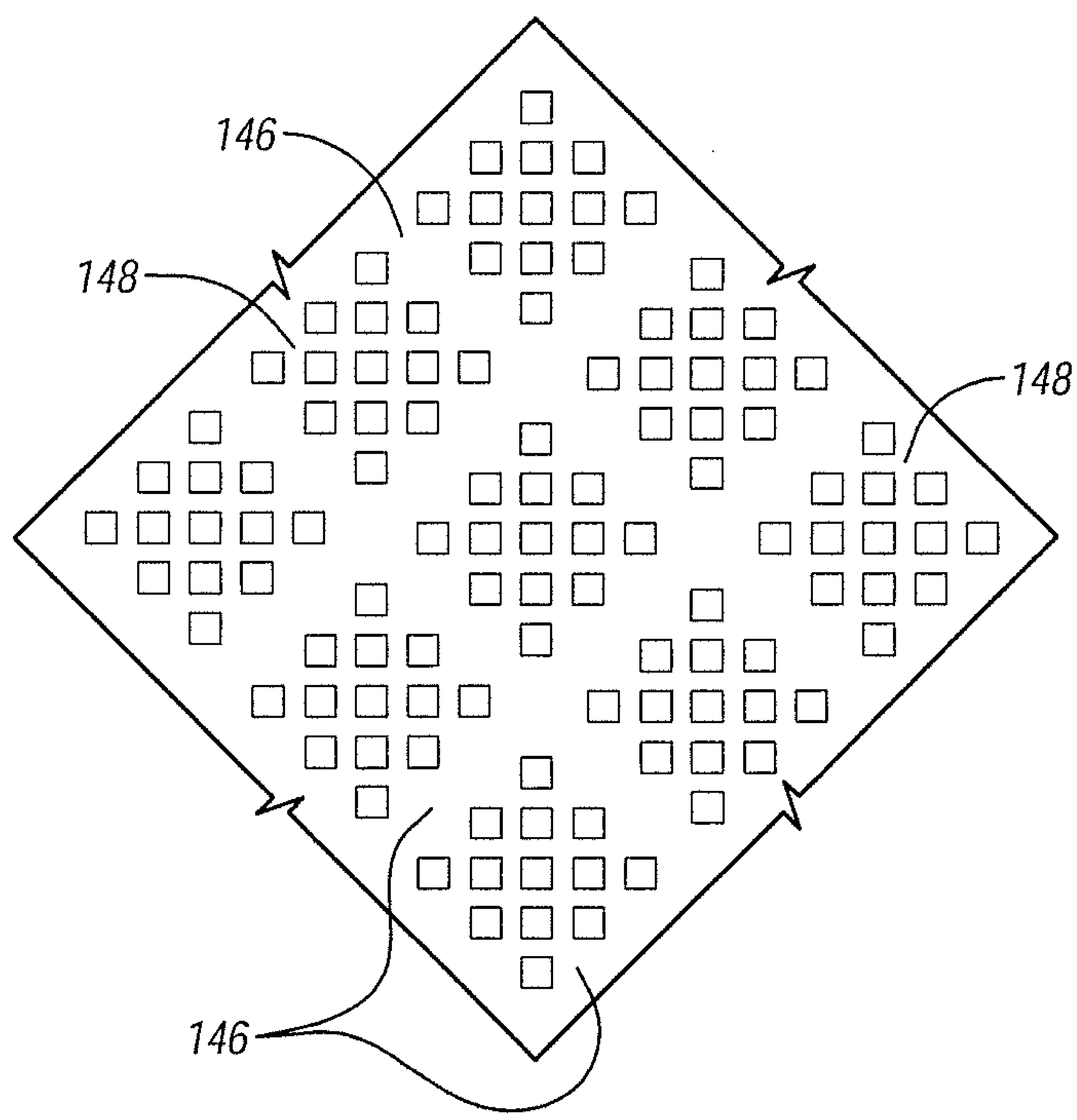


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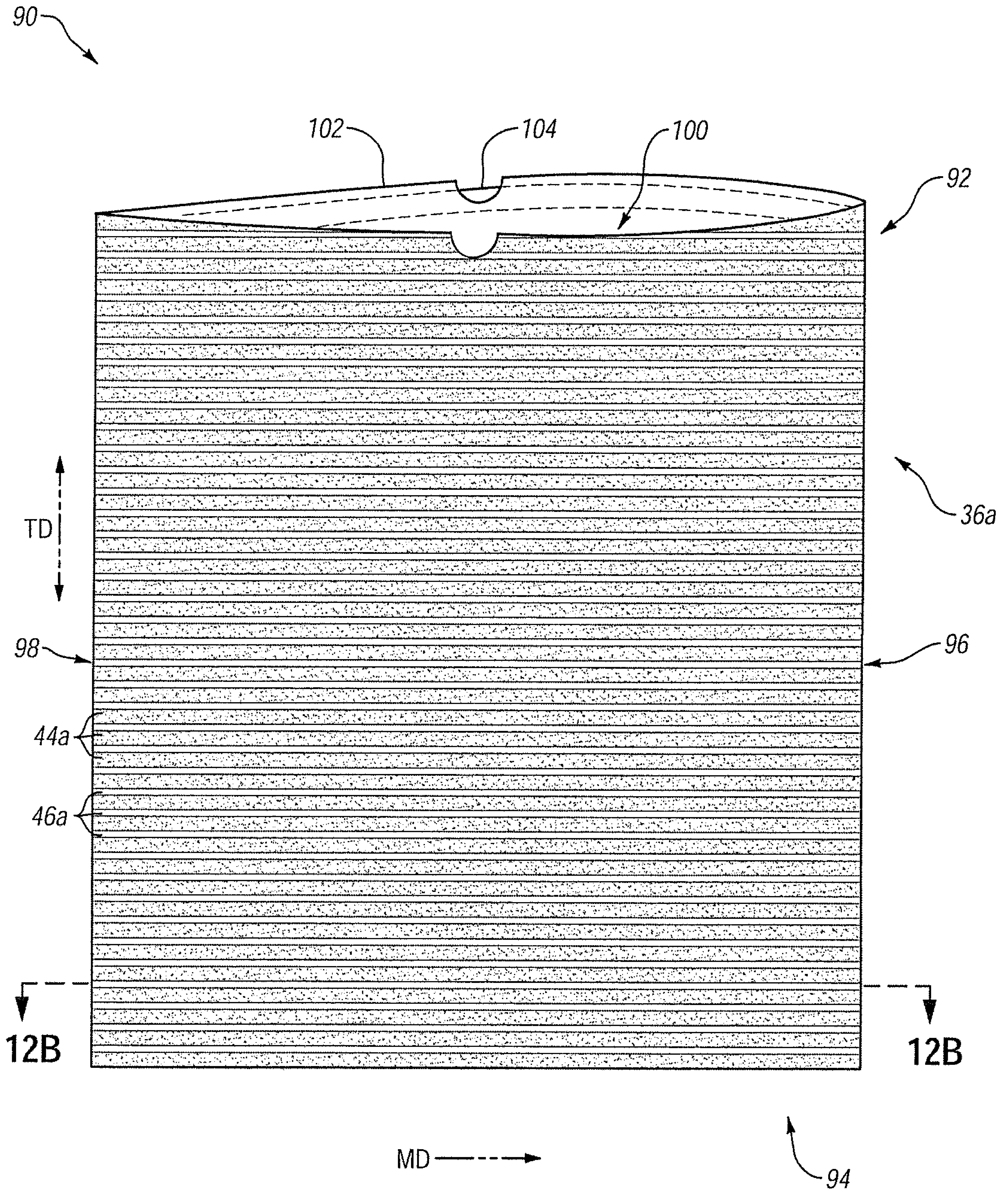


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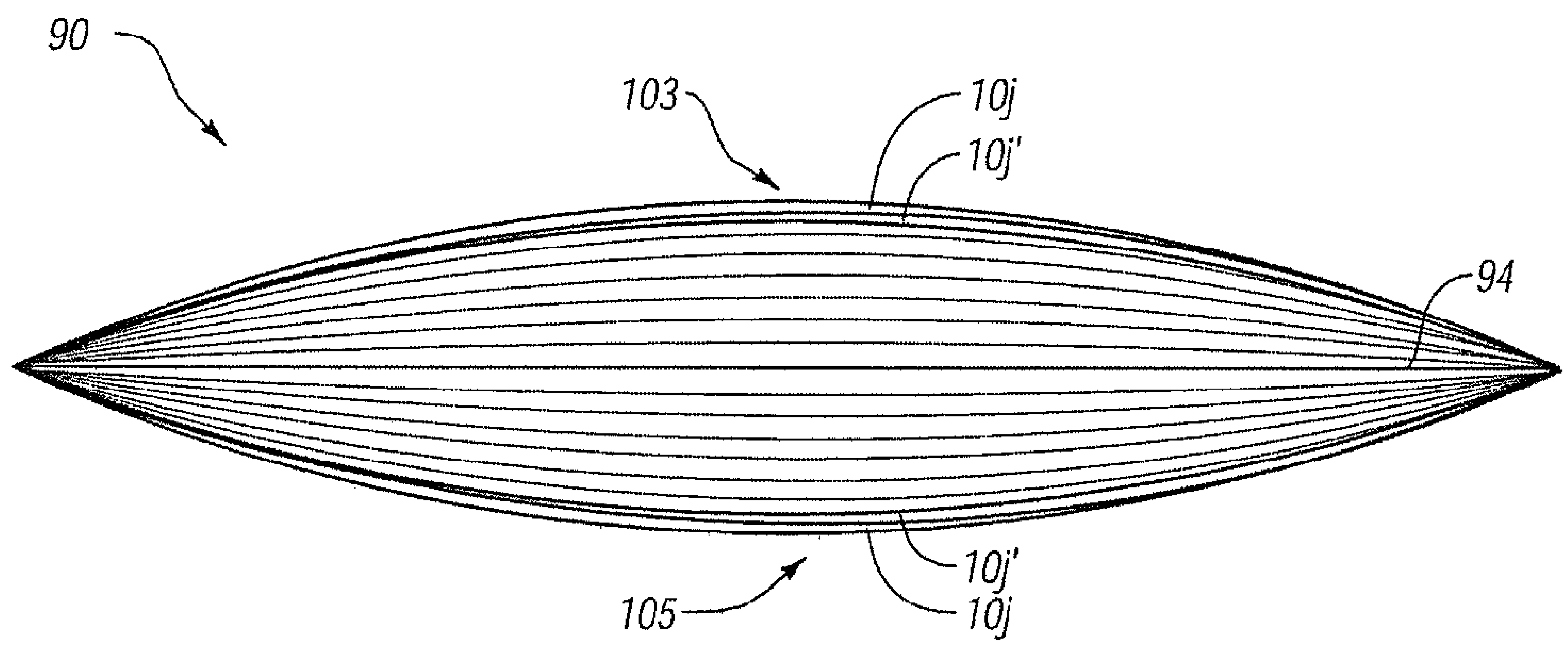


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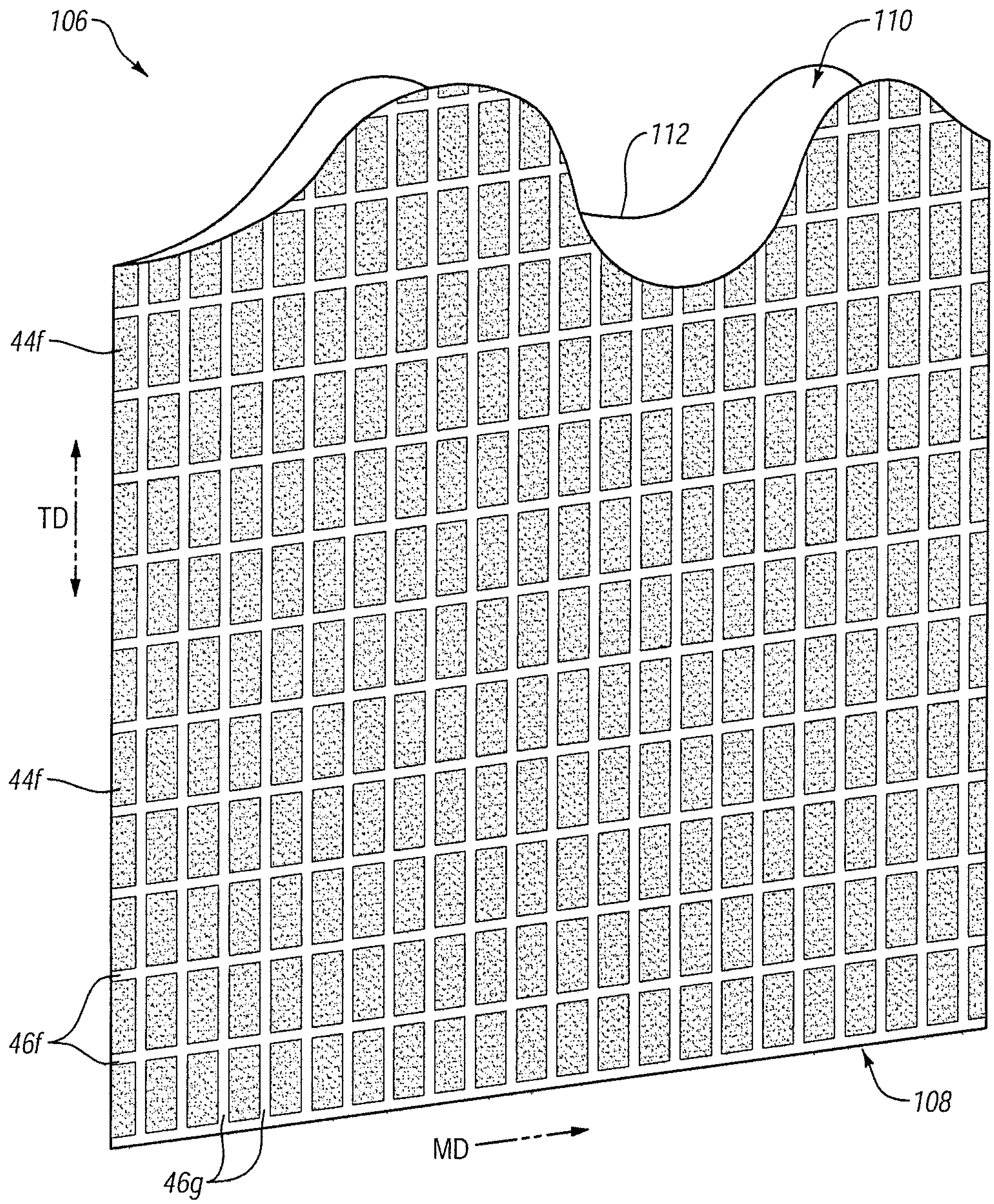
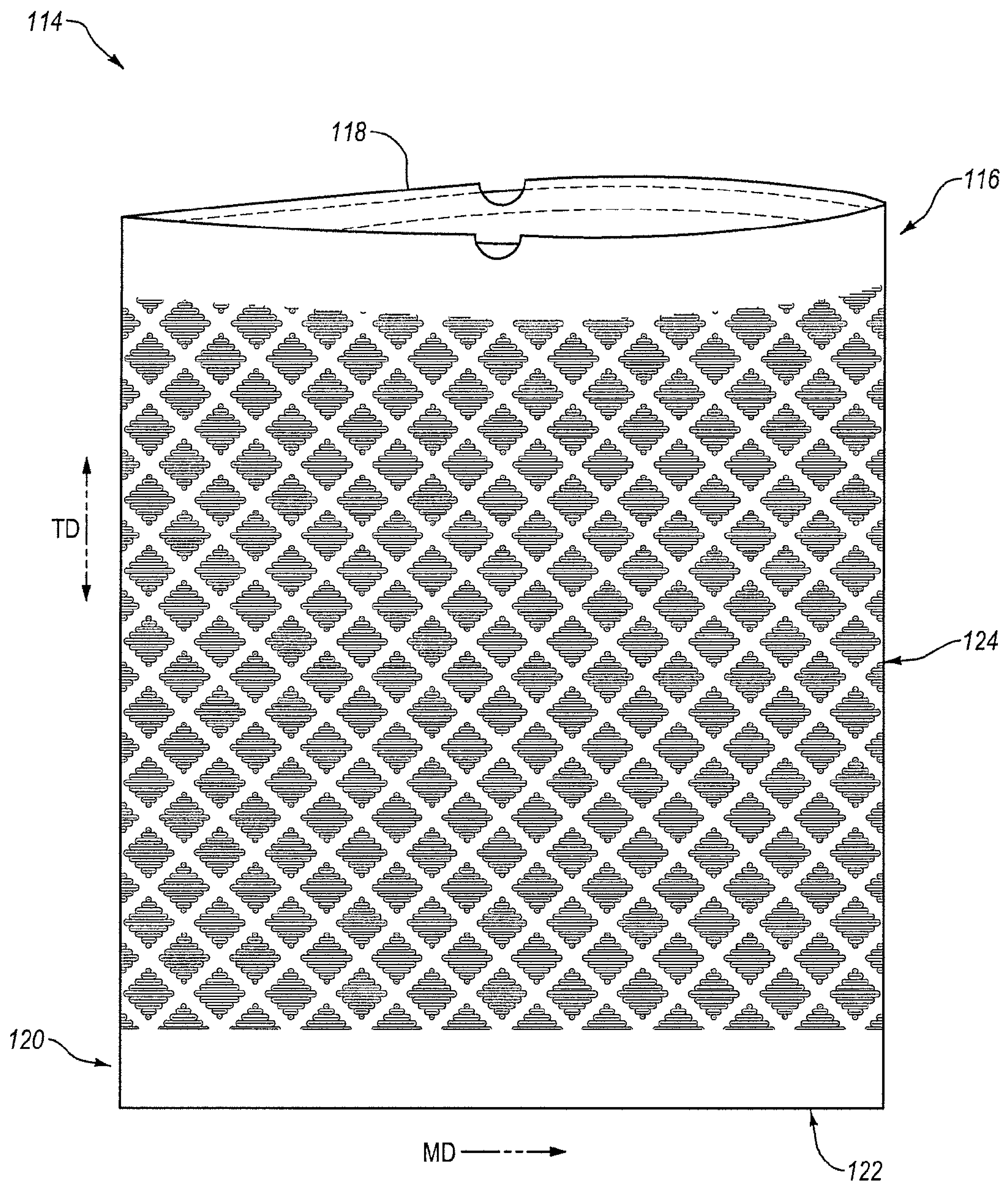



*Fig. 13*

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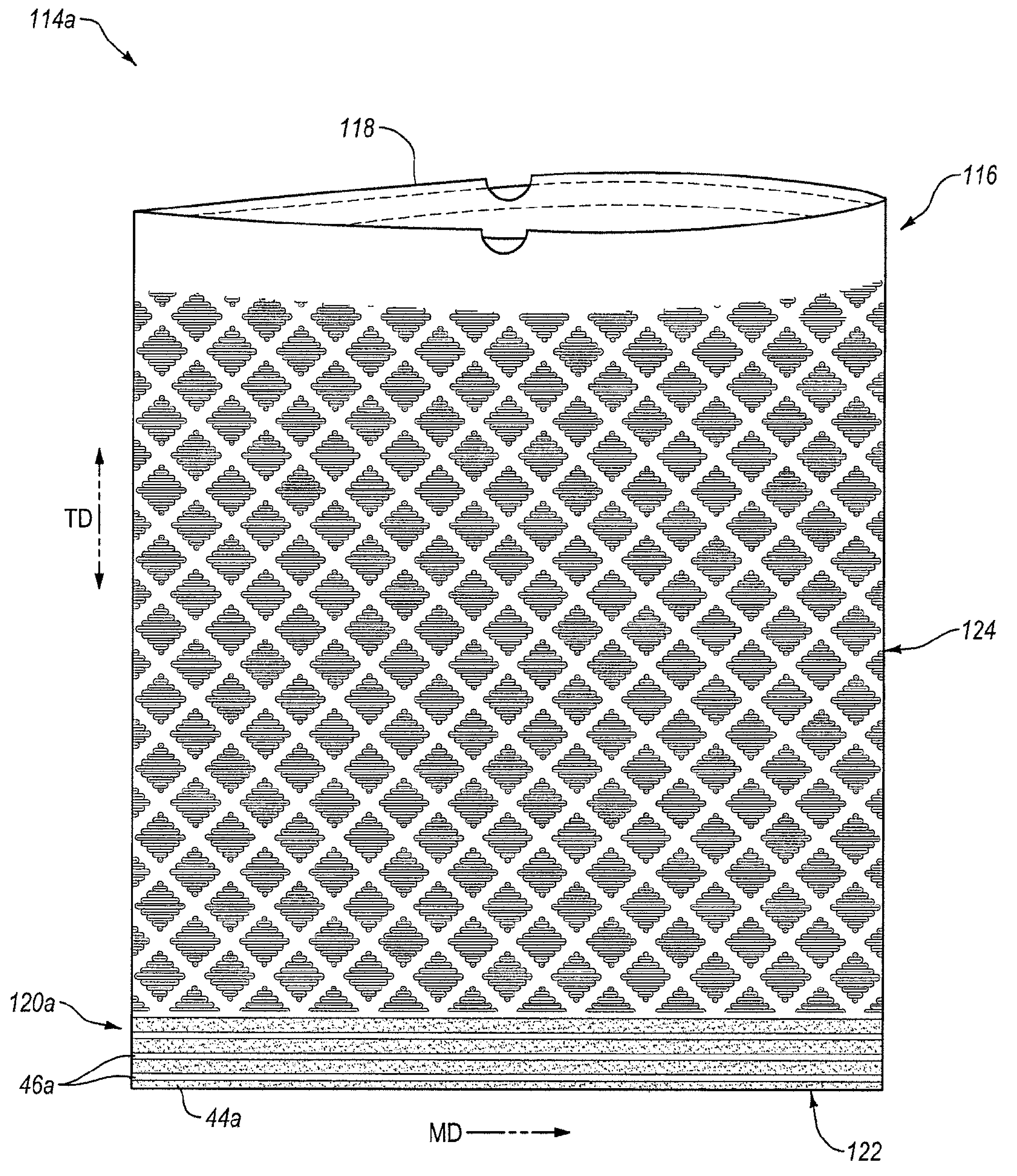


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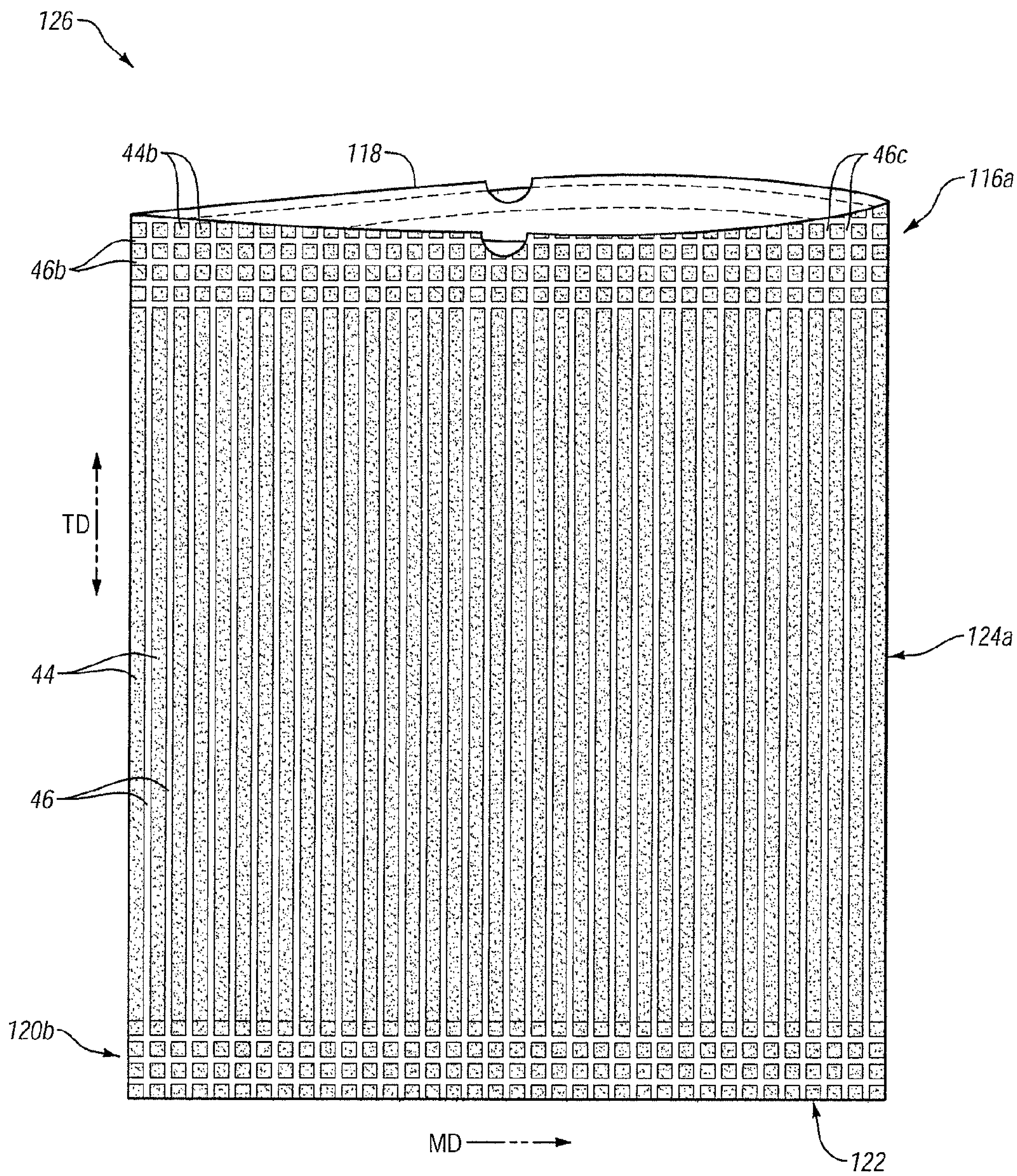


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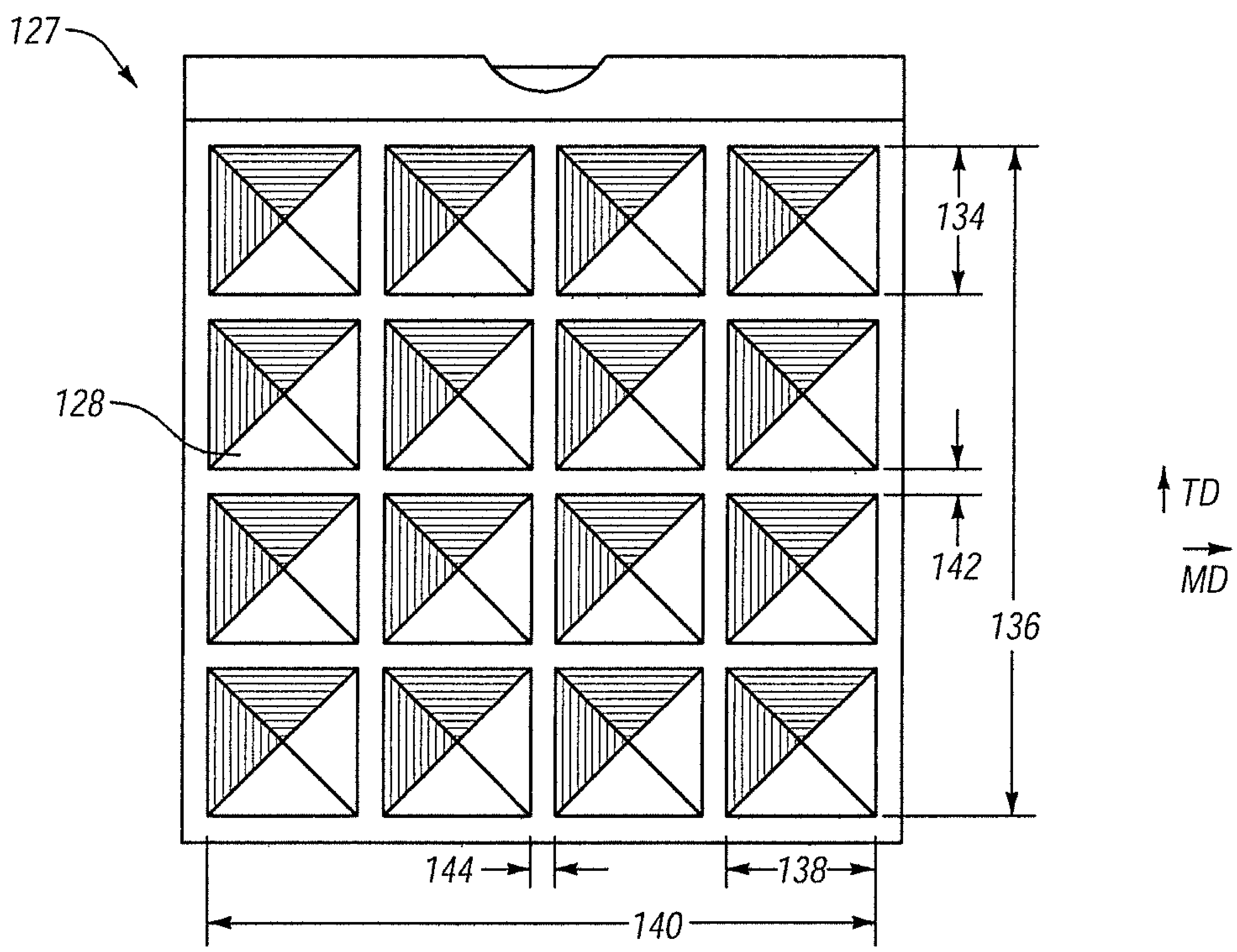
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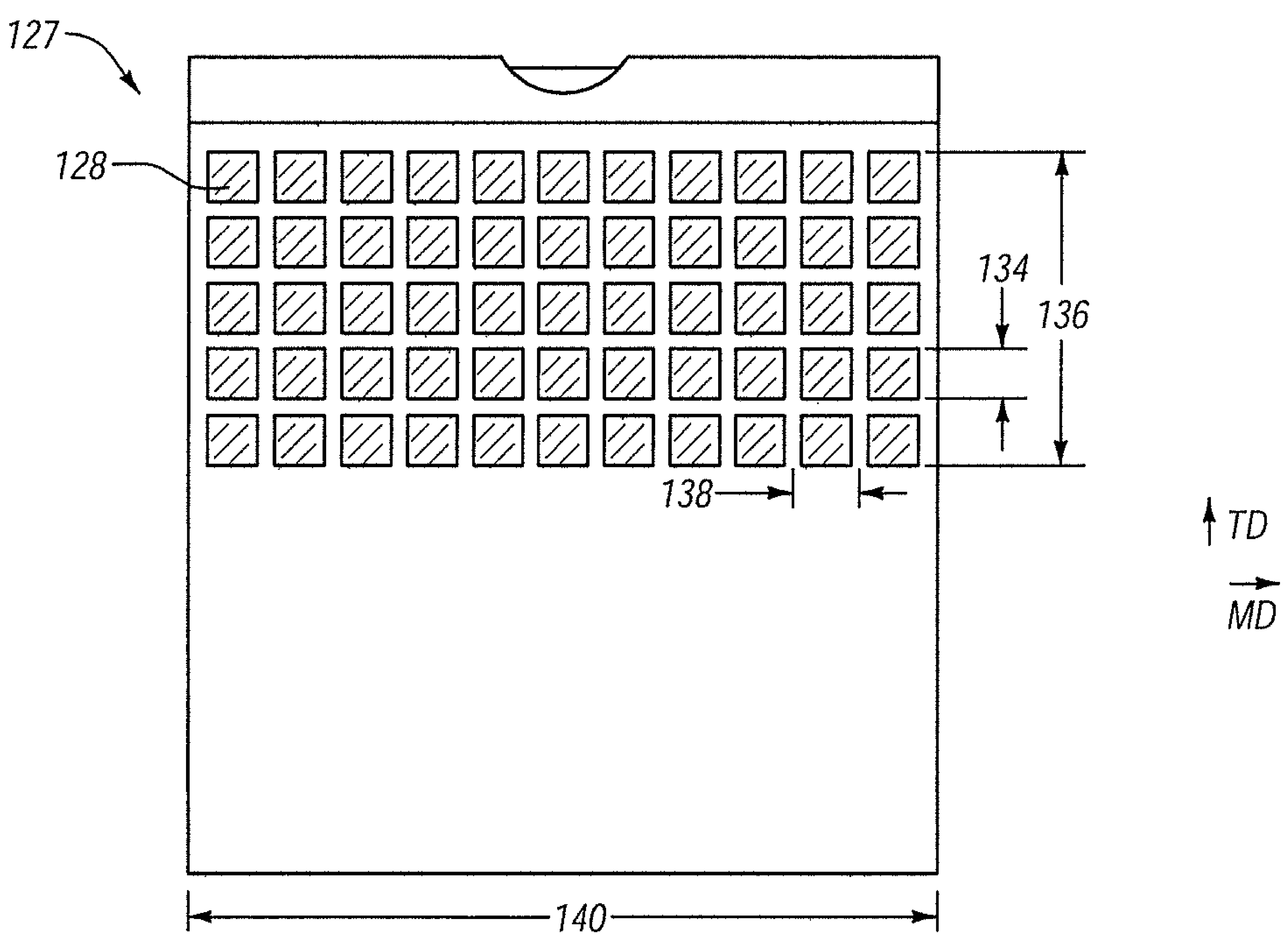
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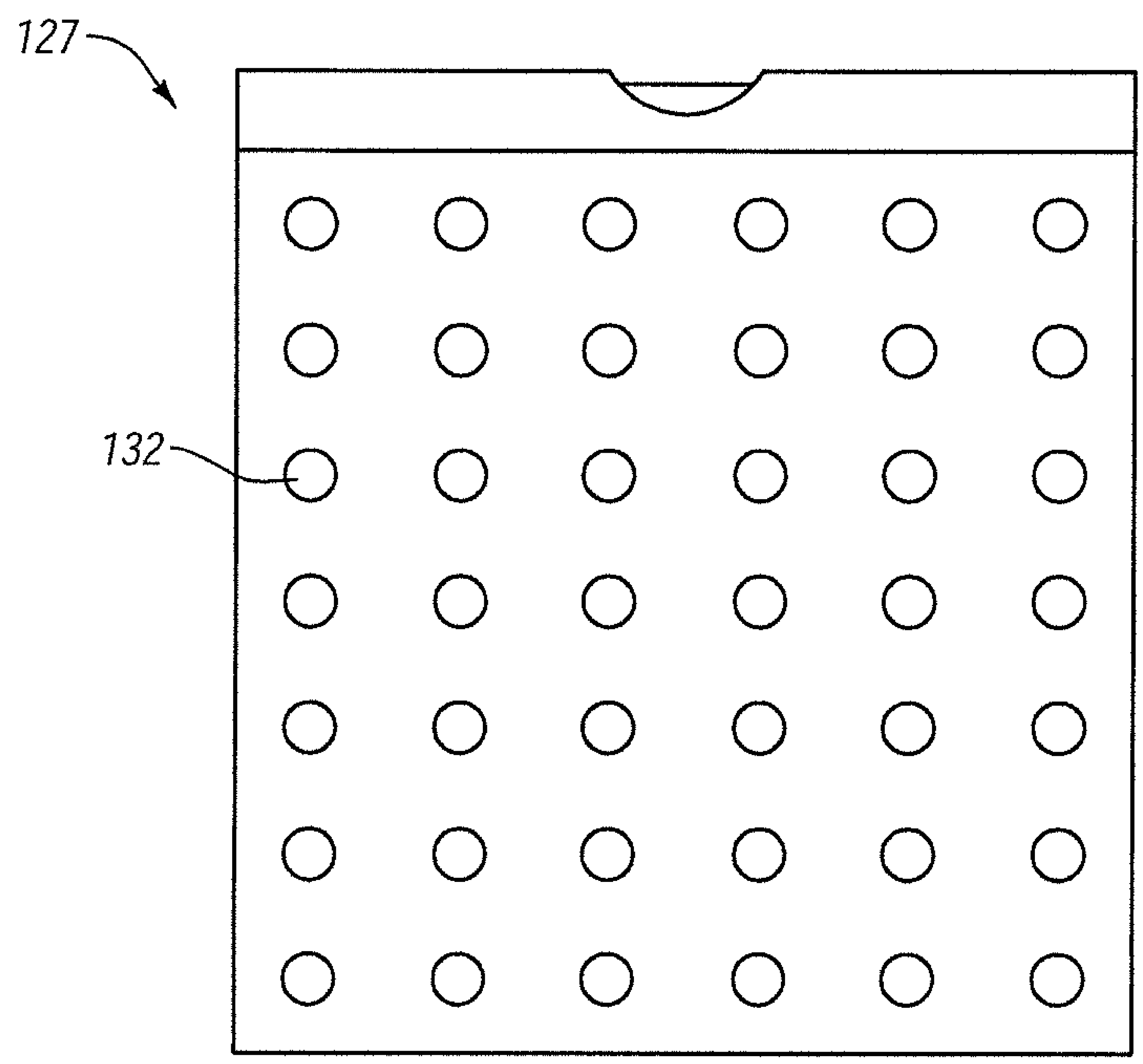


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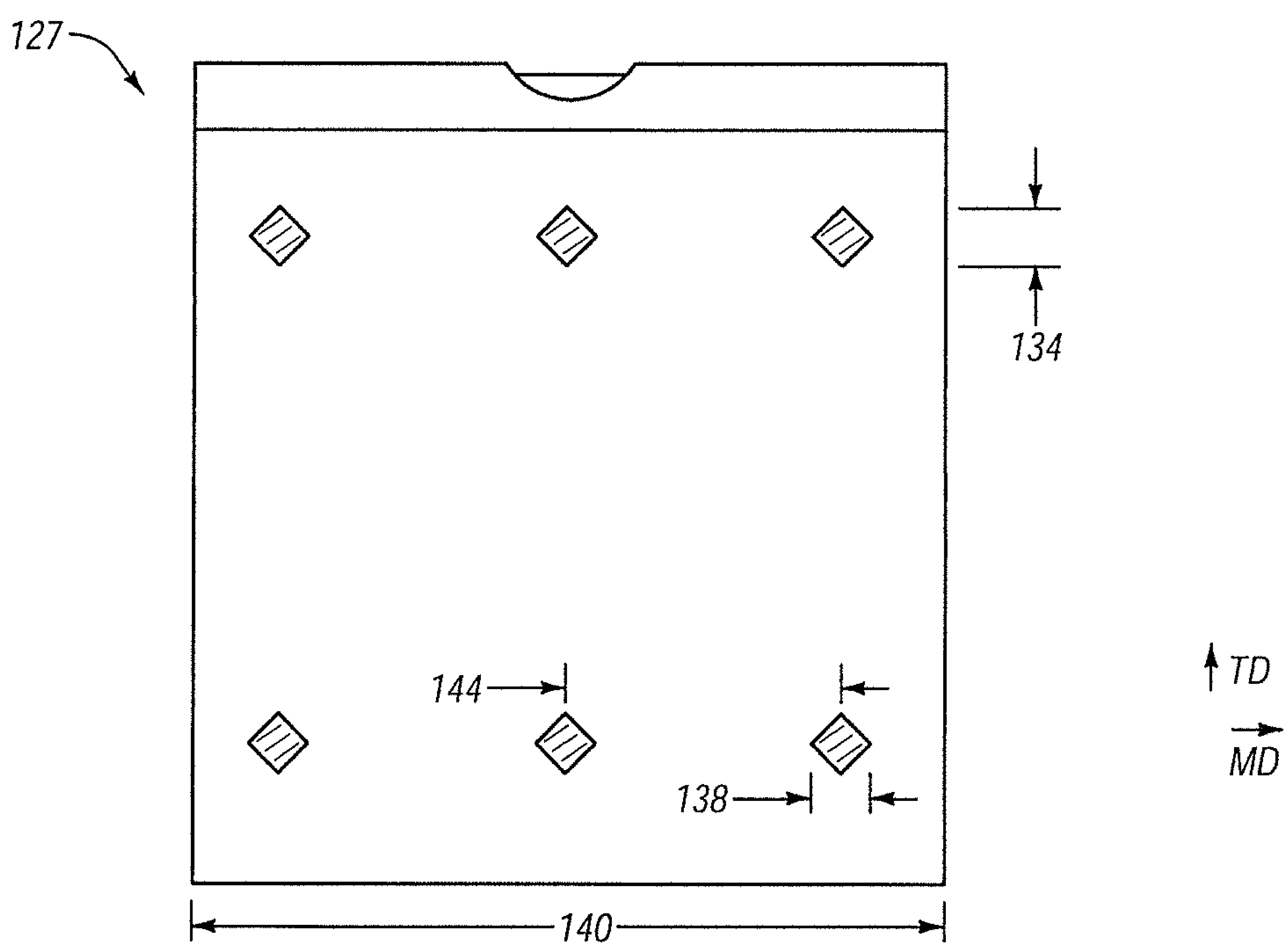


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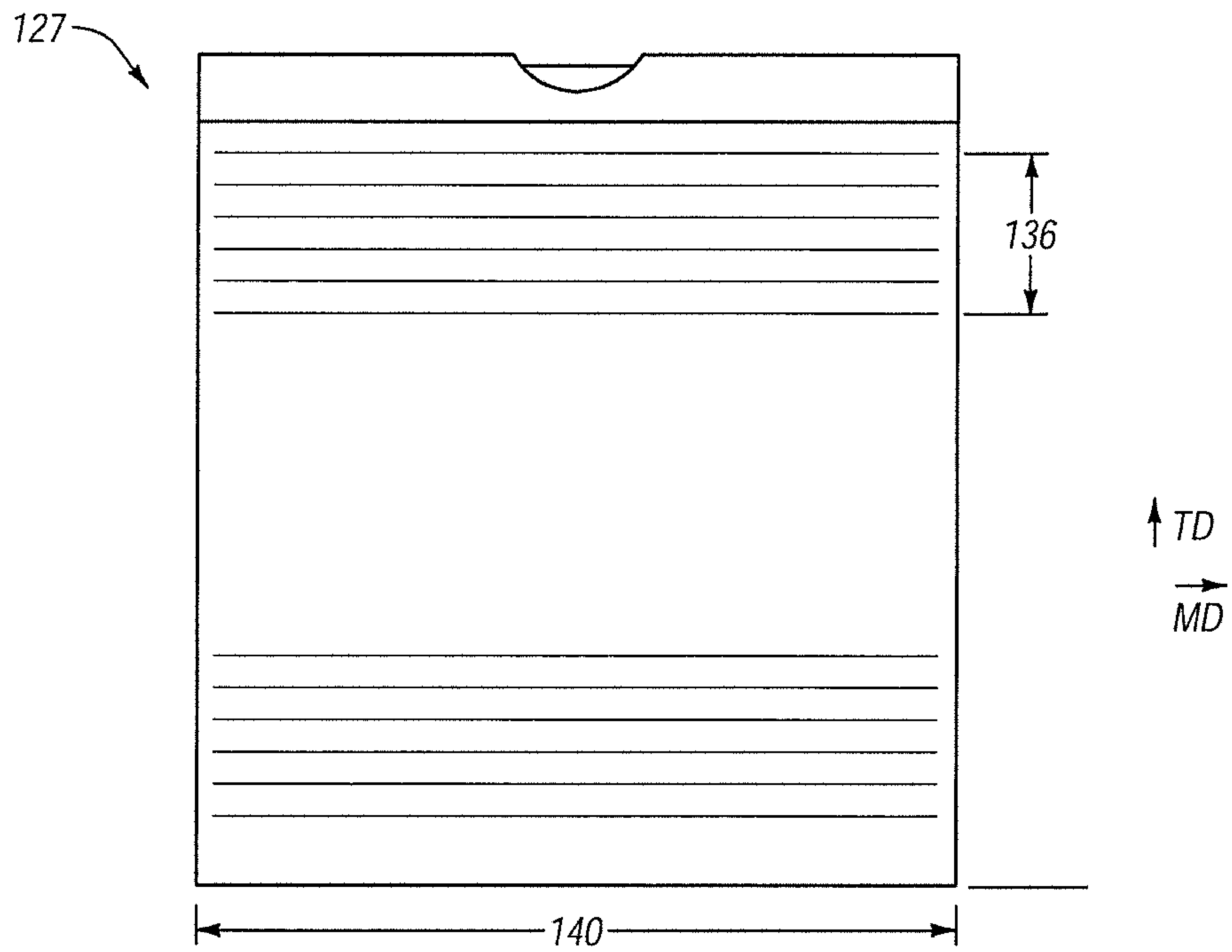


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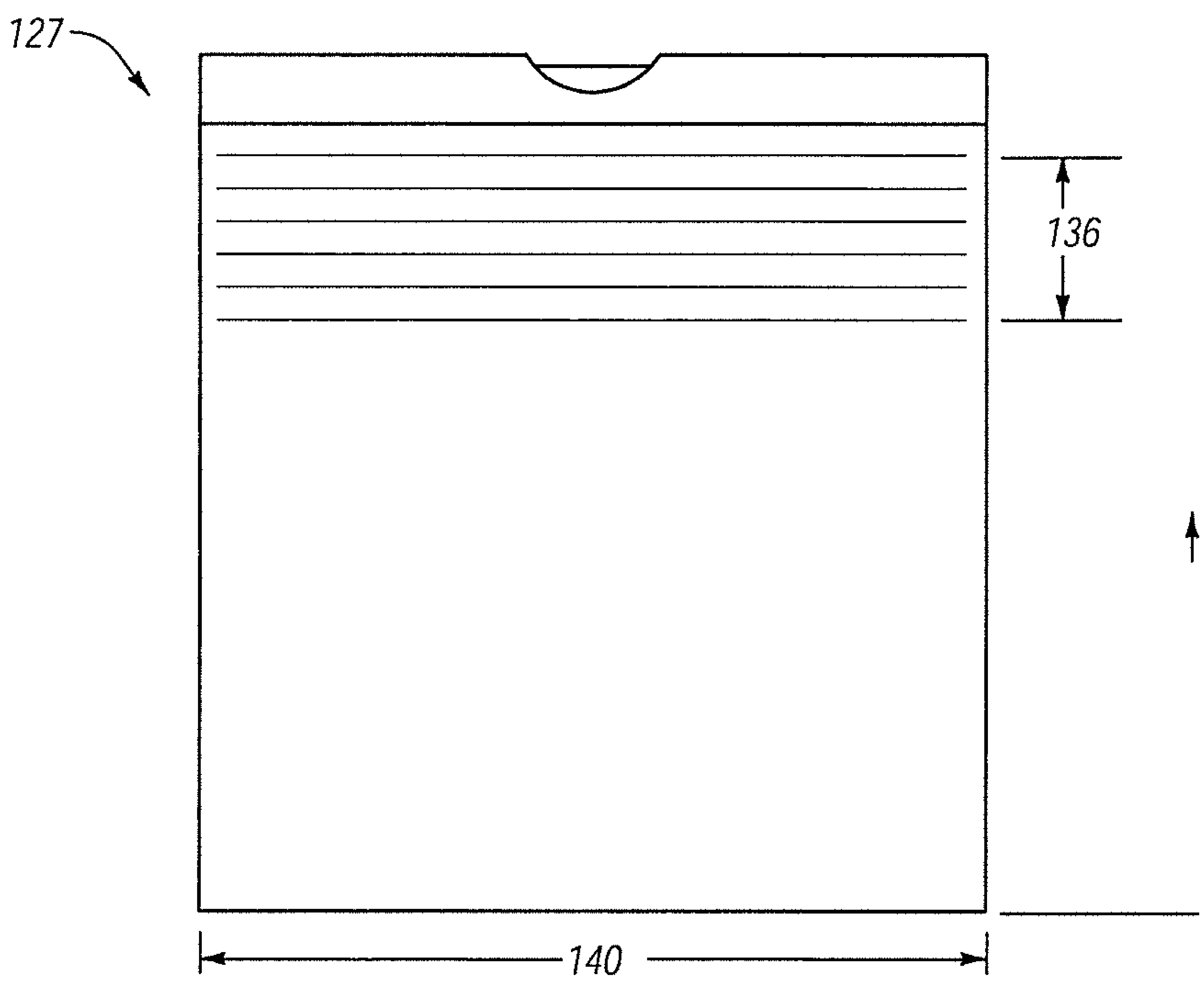


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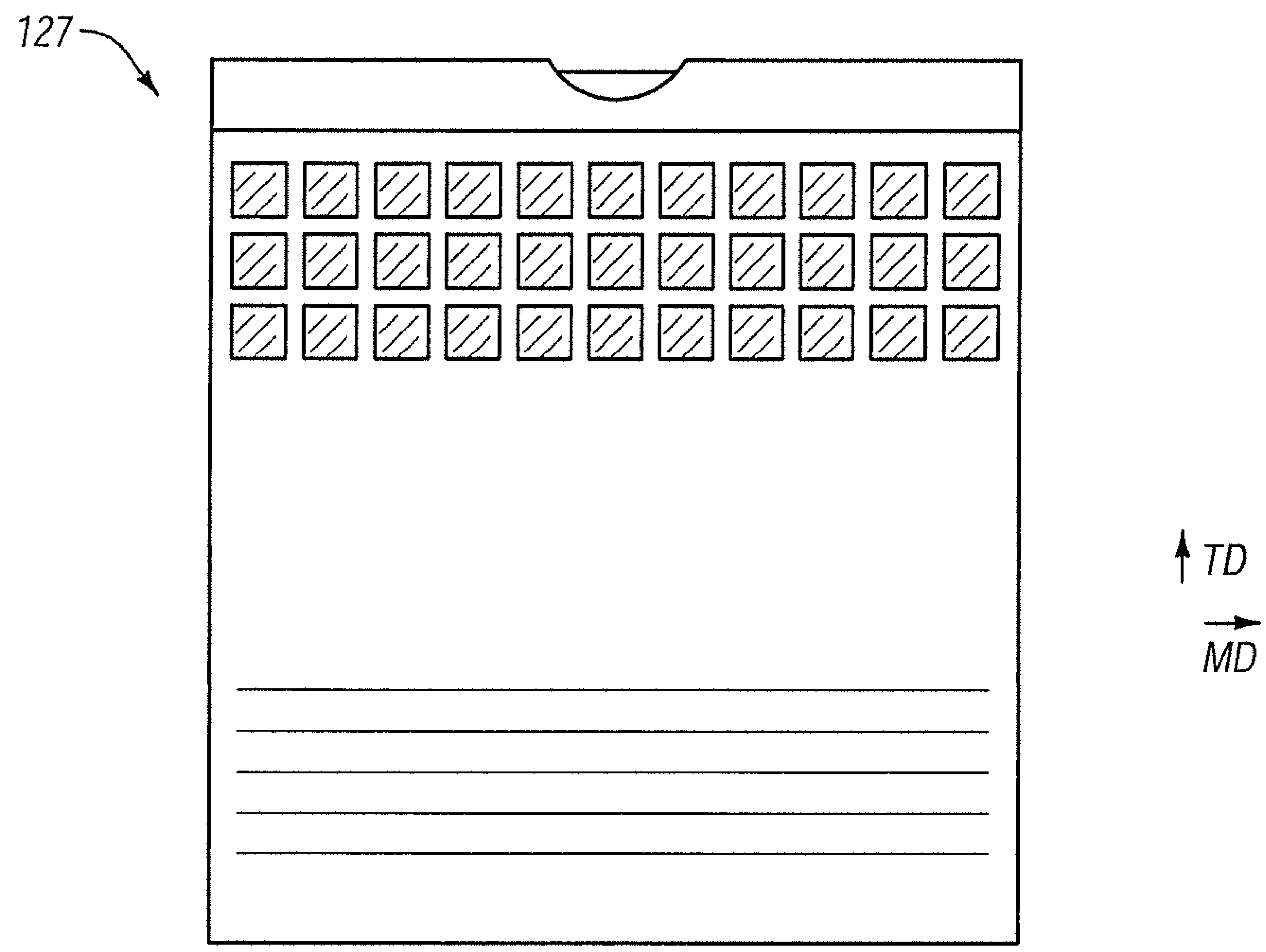


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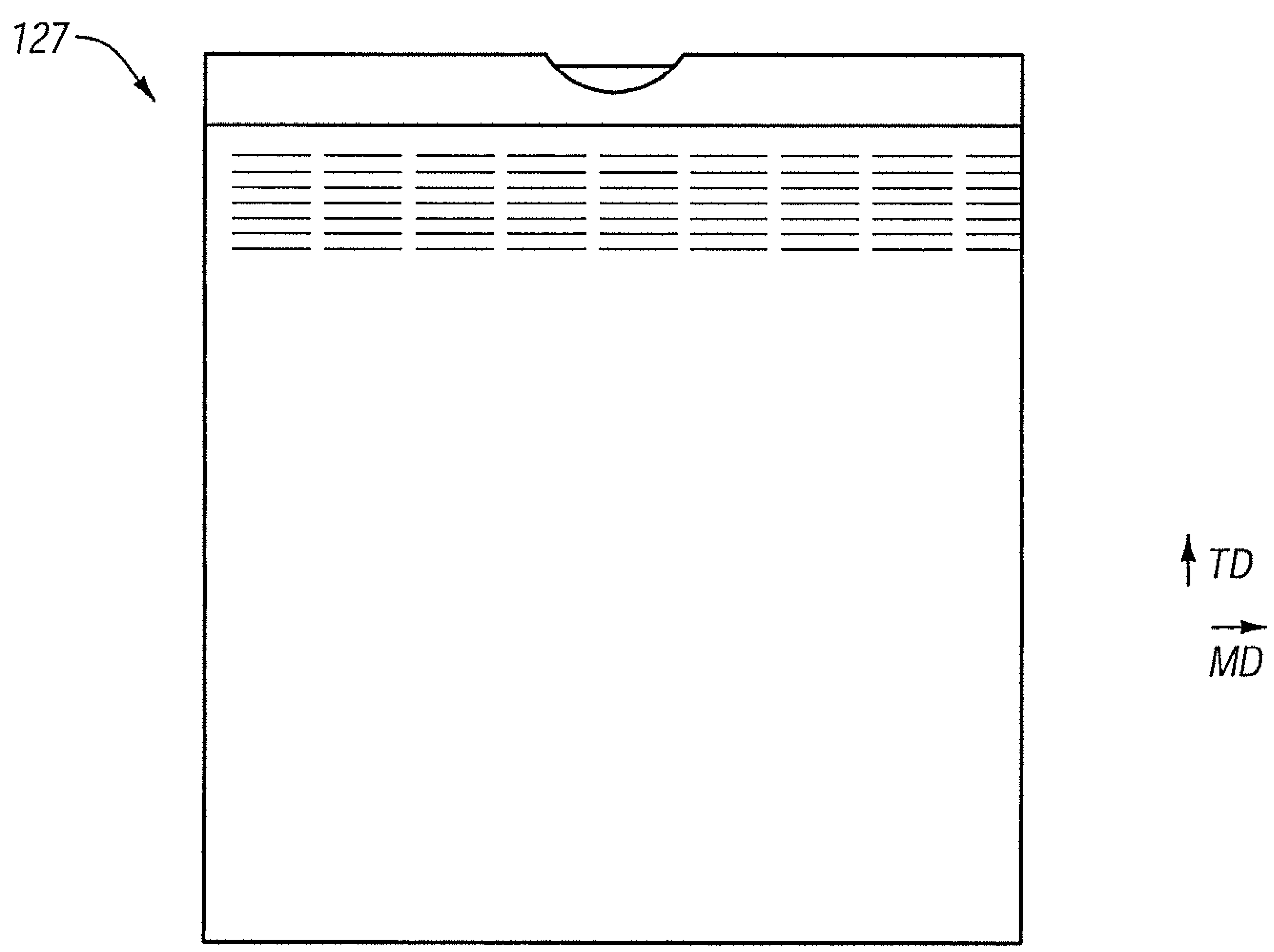


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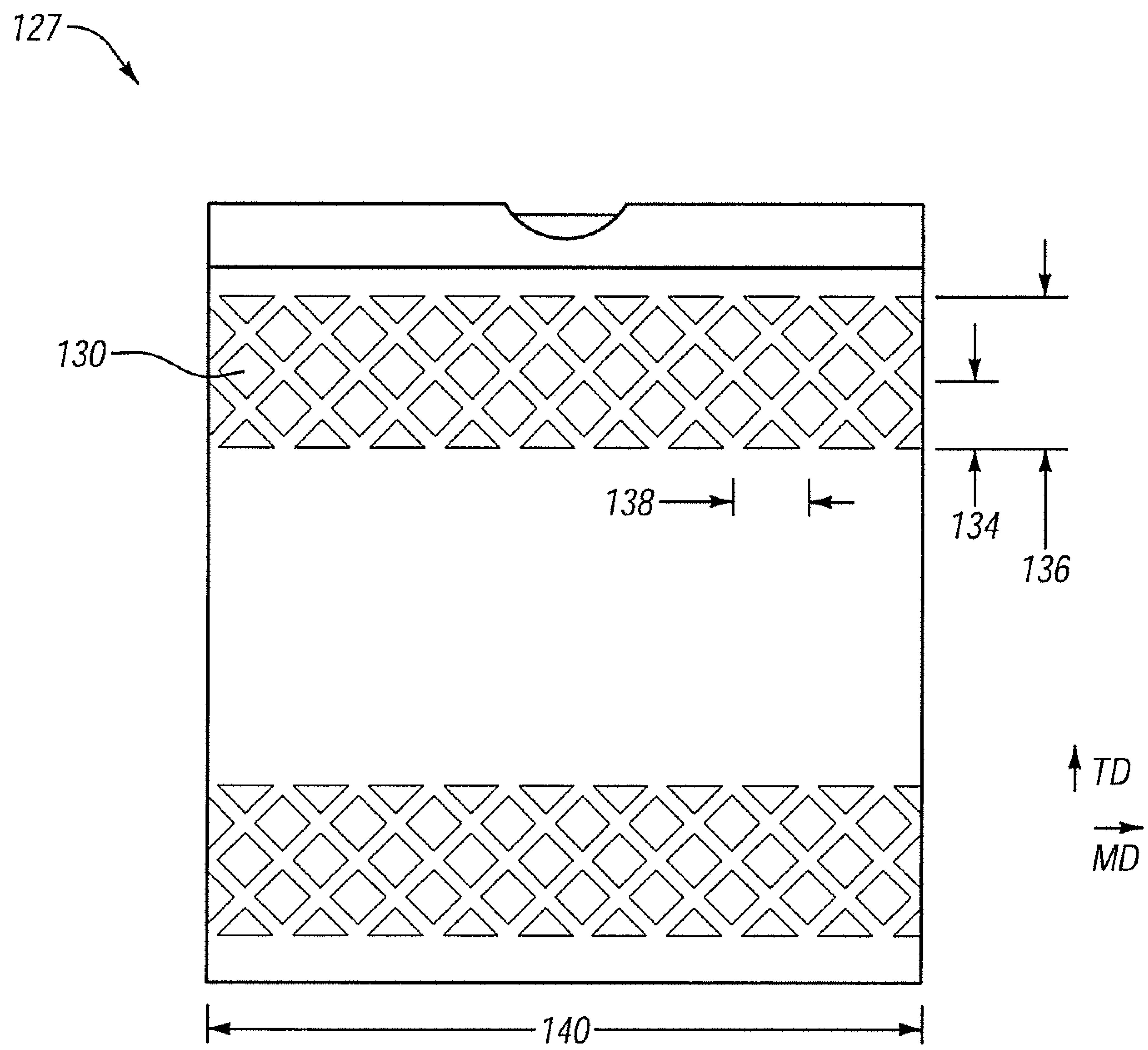


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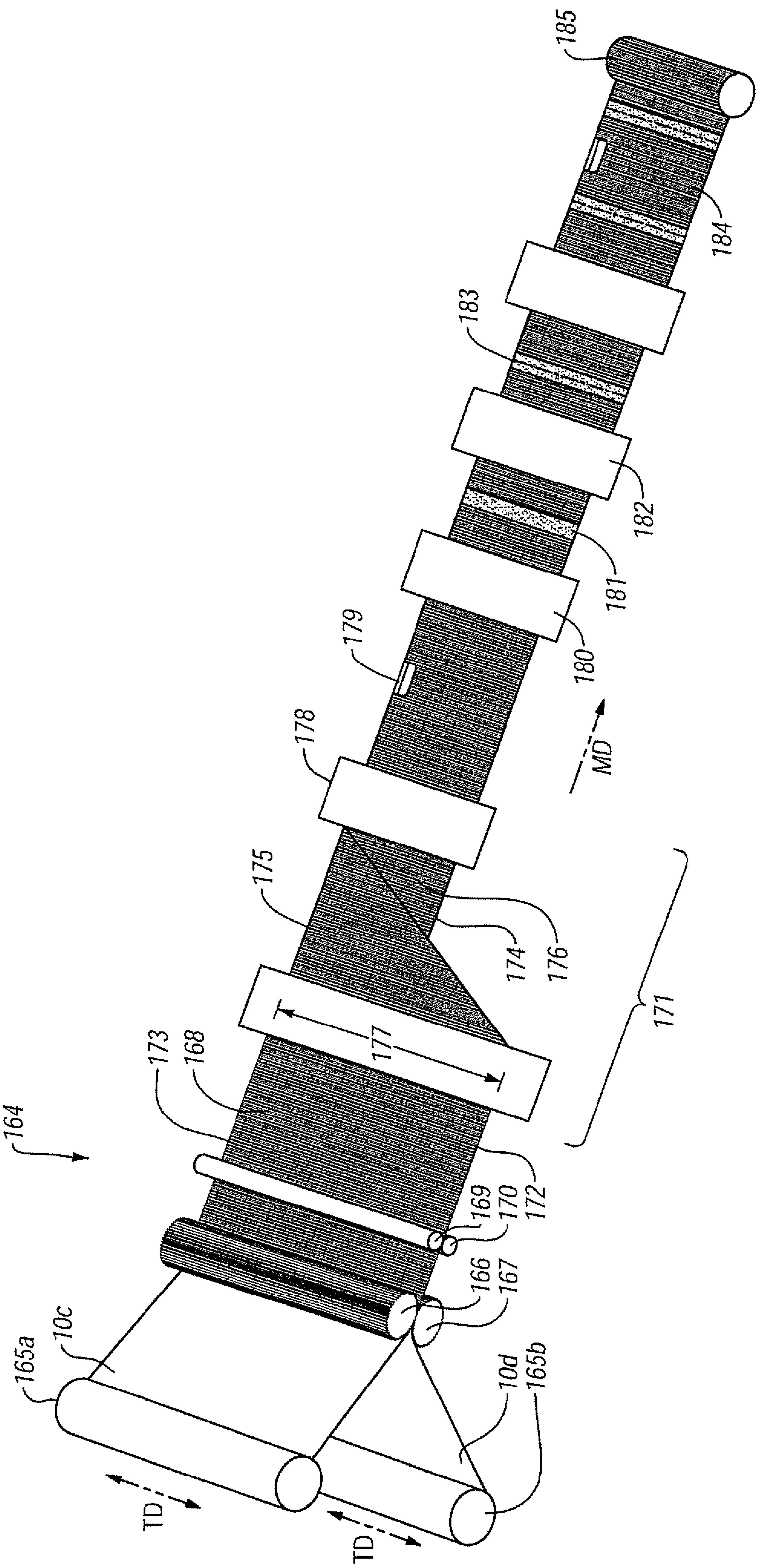
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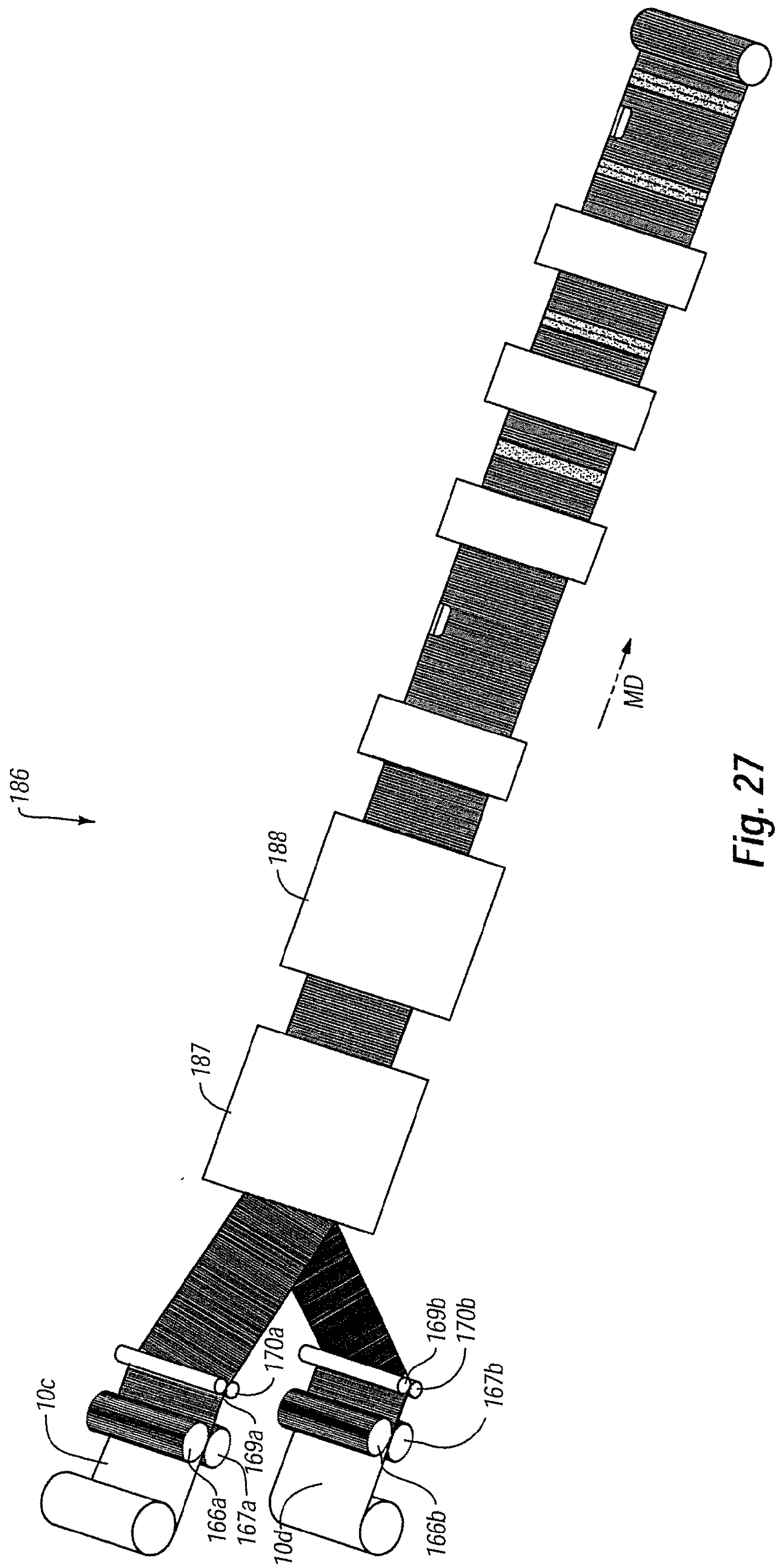
Fig. 26

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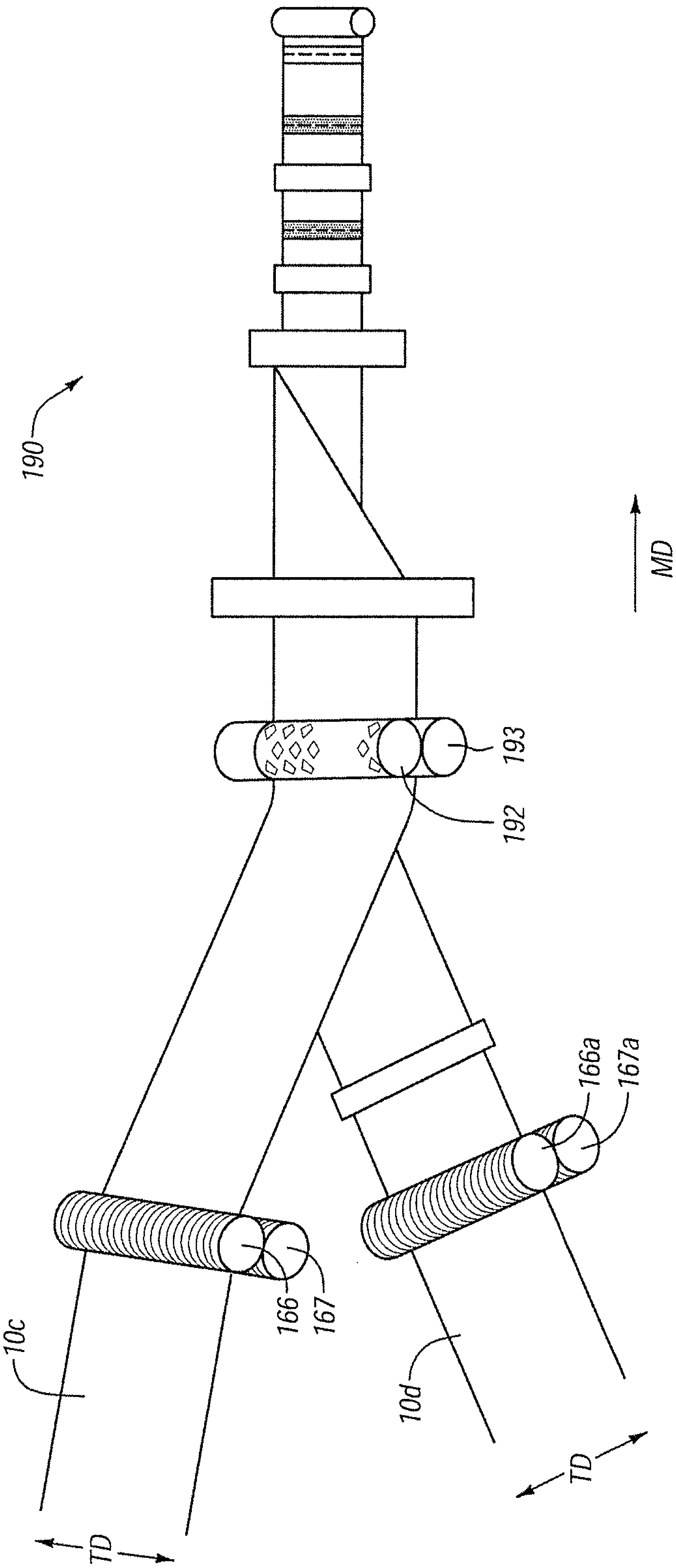


Fig. 28

# NON-CONTINUOUSLY LAMINATED MULTI-LAYERED BAGS

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a divisional of U.S. patent application Ser. No. 13/273,384 filed Oct. 14, 2011 and entitled NON-CONTINUOUSLY MULTI-LAYERED BAGS, which is a continuation in part of U.S. patent application Ser. No. 12/947,025 filed Nov. 16, 2010 and entitled DISCONTINUOUSLY LAMINATED FILM and issued on Dec. 10, 2013 as U.S. Pat. No. 8,603,609, which claims the benefit of U.S. Provisional Application No. 61/261,673, filed Nov. 16, 2009. Each of the above-referenced applications is hereby incorporated by reference in its entirety.

## BACKGROUND OF THE INVENTION

1. The Field of the Invention

The present invention relates generally to thermoplastic films. Specifically, the invention relates to stretched thermoplastic films with visually distinct regions created by stretching the films.

2. Background and Relevant Art

Thermoplastic films are a common component in various commercial and consumer products. For example, grocery bags, trash bags, sacks, and packaging materials are products that are commonly made from thermoplastic films. Additionally, feminine hygiene products, baby diapers, adult incontinence products, and many other products include thermoplastic films to one extent or another.

Thermoplastic films have a variety of different strength parameters that manufacturers of products incorporating a thermoplastic film component may attempt to manipulate to ensure that the film is suitable for use its intended use. For example, manufacturers may attempt to increase or otherwise control the tensile strength, tear resistance, and impact resistance of a thermoplastic film. One way manufacturers may attempt to control or change the material properties of a thermoplastic film is by stretching the film. Common directions of stretching include “machine direction” and “transverse direction” stretching. As used herein, the term “machine direction” or “MD” refers to the direction along the length of the film, or in other words, the direction of the film as the film is formed during extrusion and/or coating. As used herein, the term “transverse direction” or “TD” refers to the direction across the film or perpendicular to the machine direction.

Common ways of stretching film in the machine direction include machine direction orientation (“MDO”) and incremental stretching. MDO involves stretching the film between two pairs of smooth rollers. Commonly MDO involves running a film through the nips of sequential pairs of smooth rollers. The first pair of rollers rotates at a speed less than that of the second pair of rollers. The difference in speed of rotation of the pairs of rollers can cause the film between the pairs of rollers to stretch. The ratio of the roller speeds will roughly determine the amount that the film is stretched. For example, if the first pair of rollers is rotating at 100 feet per minute (“fpm”) and the second pair of rollers is rotating at 500 fpm, the rollers will stretch the film to roughly five times its original length. MDO stretches the film continuously in the machine direction and is often used to create an oriented film.

Incremental stretching of thermoplastic film, on the other hand, typically involves running the film between grooved or toothed rollers. The grooves or teeth on the rollers intermesh and stretch the film as the film passes between the rollers. Incremental stretching can stretch a film in many small increments that are spaced across the film. The depth at which the intermeshing teeth engage can control the degree of stretching. Often, incremental stretching of films is referred to as ring rolling.

In addition to allowing for the modification or tailoring of the strength of a film, stretching of a film can also reduce the thickness of the film. Stretched films of reduced thickness can allow manufacturers to use less thermoplastic material to form a product of a given surface area or size. Unfortunately, stretching thermoplastic using conventional methods can weaken the film.

One common use of thermoplastic films is as bags for liners in trash or refuse receptacles. Another common use of thermoplastic films is as flexible plastic bags for storing food items.

## BRIEF SUMMARY OF THE INVENTION

Implementations of the present invention solve one or more problems in the art with apparatus and methods for creating multi-layered non-continuously laminated films and bags with increased strength. In particular, one or more implementations provide for forming bonds between adjacent layers of a multi-layer film or bag that are relatively light such that forces acting on the multi-layer film are first absorbed by breaking the bonds rather than, or prior to, tearing or otherwise causing the failure of the layers of the multi-layer film or bag. Such implementations can provide an overall thinner film employing a reduced amount of raw material that nonetheless has maintained or increased strength parameters. Alternatively, such implementations can use a given amount of raw material and provide a film with increased strength parameters.

For example, one implementation of a thermoplastic bag with a bag-in-bag configuration includes a first thermoplastic bag, the first thermoplastic bag comprising a first pair of opposing sidewalls joined together along three edges. The thermoplastic bag also includes a second thermoplastic bag positioned within the first thermoplastic bag. The second thermoplastic bag has a second pair of opposing sidewalls joined together along three edges. Additionally, the thermoplastic bag includes a plurality of non-continuous bonded regions securing the first and second thermoplastic bags together.

Another implementation of the present invention includes a multi-layered bag comprising a first sidewall comprising a first layer of a thermoplastic material and an adjacent second layer of thermoplastic material. The multi-layered bag also includes a second sidewall comprising a first layer of a thermoplastic material and an adjacent second layer of thermoplastic material. The second sidewall is joined to the first sidewall along a first side edge, an opposing second side edge, and a bottom edge. The first and second layers of the first sidewall are non-continuously laminated together. Furthermore, the first and second layers of the second sidewall are non-continuously laminated together.

In addition to the forgoing, a method for forming a multi-layered bag having a bag-in-bag configuration may involve providing first and second thermoplastic films. The method can also involve non-continuously laminating the first thermoplastic film to the second thermoplastic film by a process selected from the group consisting of adhesive bonding, ultrasonic bonding, embossing, ring rolling, SELF-ing, and combinations thereof. Additionally, the method can involve joining at least two edges of the first thermoplastic film and the second thermoplastic film together to form a bag configuration.

Additional features and advantages of exemplary embodiments of the present invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of such exemplary embodiments. The features and advantages of such embodiments may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims. These and other features will become more fully apparent from the following description and appended claims, or may be learned by the practice of such exemplary embodiments as set forth hereinafter.

## BRIEF DESCRIPTION OF THE DRAWINGS

In order to describe the manner in which the above-recited and other advantages and features of the invention can be obtained, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. It should be noted that the figures are not drawn to scale, and that elements of similar structure or function are generally represented by like reference numerals for illustrative purposes throughout the figures. Understanding that these drawings depict only typical embodiments of the invention and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. **1**A illustrates a schematic diagram of a multi-layered film being lightly laminated by MD intermeshing rollers in accordance with one or more implementations of the present invention;

FIG. **1**B illustrates an enlarged view of two initially separate thermoplastic films passing together through the intermeshing rollers of FIG. **1**A taken along the circle **1**B of FIG. **1** to form a multi-layered lightly-laminated;

FIG. **1**C illustrates an enlarged view of three initially separate thermoplastic films passing together through the intermeshing rollers of FIG. **1**A to form a multi-layered lightly-laminated;

FIG. **2** illustrates a view of a multi-layered lightly-laminated thermoplastic film created by the intermeshing rollers of FIG. **1**A;

FIG. **3** illustrates a schematic diagram of a multi-layered thermoplastic film being lightly laminated by TD intermeshing rollers in accordance with one or more implementations of the present invention;

FIG. **4** illustrates a view of a multi-layered lightly-laminated thermoplastic film created by the intermeshing rollers of FIG. **3**;

FIG. **5** illustrates a view of a multi-layered lightly-laminated thermoplastic film created by the intermeshing rollers of both FIG. **1**A and FIG. **3**;

FIG. **6** illustrates a view of a multi-layered lightly-laminated thermoplastic film created by diagonal direction intermeshing rollers in accordance with one or more implementations of the present invention;

FIG. **7** illustrates a schematic diagram of a set of intermeshing rollers used to form a structural elastic like film (SELF) by imparting strainable networks into the film while lightly laminating adjacent layers of a film in accordance with one or more implementations of the present invention;

FIG. **8** illustrates a view of a multi-layered lightly-laminated thermoplastic film created by the intermeshing rollers of FIG. **7**;

FIG. **9** illustrates a view of another multi-layered lightly-laminated thermoplastic film including strainable networks in accordance with one or more implementations of the present invention;

FIG. **10**A illustrates a view of yet another multi-layered lightly-laminated thermoplastic film including strainable networks in accordance with one or more implementations of the present invention;

FIG. **10**B illustrates a cut away perspective view across and through the block pattern of FIG. **10**A;

FIG. **11**A illustrates a schematic diagram of another implementation of intermeshing rollers for use in accordance with one or more implementations of the present invention;

FIG. **11**B illustrates a close up of the protrusions and intermeshing recessions of the rollers of FIG. **11**A;

FIG. **11**C illustrates a view of a multi-layered lightly-laminated thermoplastic film created by the intermeshing rollers of FIG. **11**A;

FIG. **12**A illustrates a bag incorporating the multi-layered lightly-laminated film of FIG. **4**;

FIG. **12**B illustrates a cross-sectional view of the bag of FIG. **12**A taken along the line **12**B-**12**B of FIG. **12**A;

FIG. **13** illustrates a bag incorporating a multi-layered lightly-laminated film in accordance with one or more implementations of the present invention;

FIG. **14** illustrates a bag incorporating a middle section having lightly bonded regions in accordance with one or more implementations of the present invention;

FIG. **15** illustrates a bag incorporating sections of different patterns of lightly bonded regions in accordance with one or more implementations of the present invention;

FIG. **16** illustrates another bag incorporating sections of different patterns of lightly bonded regions in accordance with one or more implementations of the present invention;

FIG. **17** illustrates another bag incorporating a multi-layered lightly-laminated film with another pattern in accordance with one or more implementations of the present invention;

FIG. **18** illustrates another bag incorporating a top section having lightly bonded regions in accordance with one or more implementations of the present invention;

FIG. **19** illustrates another bag incorporating a multi-layered lightly-laminated film with another bond pattern in accordance with one or more implementations of the present invention;

FIG. **20** illustrates a bag incorporating a multi-layered lightly-laminated film with yet another bond pattern in accordance with one or more implementations of the present invention;

FIG. **21** illustrates another bag incorporating a top section and a bottom section having lightly bonded regions in accordance with one or more implementations of the present invention;

FIG. **22** illustrates another bag incorporating a top section having lightly bonded regions in accordance with one or more implementations of the present invention;

FIG. **23** illustrates another bag incorporating a top section and a bottom section having lightly bonded regions, each of a different pattern, in accordance with one or more implementations of the present invention;

FIG. **24** illustrates another bag incorporating a top section having lightly bonded regions in accordance with one or more implementations of the present invention;

FIG. **25** illustrates still another bag incorporating a top section and a bottom section having lightly bonded regions in accordance with one or more implementations of the present invention;

FIG. **26** illustrates a schematic diagram of a bag manufacturing process in accordance with one or more implementations of the present invention;

FIG. **27** illustrates a schematic diagram of another bag manufacturing process in accordance with one or more implementations of the present invention; and

FIG. **28** illustrates a schematic diagram of another bag manufacturing process in accordance with one or more implementations of the present invention.

## DETAILED DESCRIPTION

One or more implementations of the present invention include apparatus and methods for creating multi-layered non-continuously laminated films and bags with increased strength. In particular, one or more implementations provide for forming bonds between adjacent layers of a multi-layer film or bag that are relatively light such that forces acting on the multi-layer film are first absorbed by breaking the bonds rather than, or prior to, tearing or otherwise causing the failure of the layers of the multi-layer film or bag. Such implementations can provide an overall thinner film employing a reduced amount of raw material that nonetheless has maintained or increased strength parameters. Alternatively, such implementations can use a given amount of raw material and provide a film with increased strength parameters.

In particular, the non-continuous bonds or bond regions of adjacent layers of multi-layer films or bags in accordance with one or more implementations can act to first absorb forces via breaking of the bonds prior to allowing that same force to cause failure of the individual layers of the multi-layer film or bag. Such action can provide increased strength to the multi-layer film or bag. In one or more implementations, the non-continuous bonds or bond regions include a bond strength that is advantageously less than a weakest tear resistance of each of the individual films so as to cause the bonds to fail prior to failing of the film layers. Indeed, one or more implementations include bonds that the release just prior to any localized tearing of the layers of the multi-layer bag.

Thus, in one or more implementations, the non-continuous bonds or bond regions of a multi-layer film or bag can fail before either of the individual layers undergo molecular-level deformation. For example, an applied strain can pull the non-continuous bonds or bond regions apart prior to any molecular-level deformation (stretching, tearing, puncturing, etc.) of the individual film layers. In other words, the light bonds or bond regions can provide less resistive force to an applied strain than molecular-level deformation of any of the layers of the multi-layer film or bag. The inventors have surprisingly found that such a configuration of light bonding can provide increased strength properties to the multi-layer film or bag as compared to a film or bag with a monolayer equal thickness or a multi-layer film or bag in which the plurality of layers are tightly bonded together (e.g., coextruded).

One or more implementations of the present invention provide for tailoring the bonds or bond regions between layers of a multi-layer bag to ensure light bonding and associated increased strength. For example, one or more implementations include modifying or tailoring one or more of a bond strength, bond density, bond pattern, or bond size between adjacent layers of a multi-layer film or bag to deliver a film with strength characteristics better than or equal to the sum of the strength characteristics of the individual layers. Such bond tailoring can allow for multi-layer films or bags having a lower basis weight (amount of raw material) to perform the same as or better than higher basis weight mono-layer or co-extruded films or bags.

Relatively weak bonding of the two or more layers of the multi-layer film or bag can be accomplished through one or more suitable techniques. For example, bonding may be achieved by pressure (for example MD ring rolling, TD ring rolling, stainable network lamination, or embossing), or with a combination of heat and pressure. Alternately, the film layers can be lightly laminated by ultrasonic bonding. Alternately, the films can be laminated by adhesives. Treatment with a Corona discharge can enhance any of the above methods. Prior to lamination, the separate layers can be flat film or can be subject to separate processes, such as stretching, slitting, coating and printing, and corona treatment.

As used herein, the terms "lamination," "laminate," and "laminated film," refer to the process and resulting product made by bonding together two or more layers of film or other material. The term "bonding", when used in reference to bonding of multiple layers of a multi-layer film, may be used interchangeably with "lamination" of the layers. According to methods of the present invention, adjacent layers of a multi-layer film are laminated or bonded to one another. The bonding purposely results in a relatively weak bond between the layers that has a bond strength that is less than the strength of the weakest layer of the film. This allows the lamination bonds to fail before the film layer, and thus the film, fails.

The term laminate is also inclusive of coextruded multi-layer films comprising one or more tie layers. As a verb, "laminate" means to affix or adhere (by means of, for example, adhesive bonding, pressure bonding, ultrasonic bonding, corona lamination, and the like) two or more separately made film articles to one another so as to form a multi-layer structure. As a noun, "laminate" means a product produced by the affixing or adhering just described.

The individual layers of the multi-layer film may each themselves comprise a plurality of laminated layers. Such layers may be significantly more tightly bonded together than the bonding provided by the purposely weak non-continuous bonding in the finished multi-layer film. Both tight and relatively weak lamination can be accomplished by joining layers by mechanical pressure, joining layers with adhesives, joining with heat and pressure, spread coating, extrusion coating, and combinations thereof. Adjacent sub-layers of an individual layer may be coextruded. Coextrusion results in tight bonding so that the bond strength is greater than the tear resistance of the resulting laminate (i.e., rather than allowing adjacent layers to be peeled apart through breakage of the lamination bonds, the film will tear).

In one or more implementations, the light lamination or bonding between layers of a multi-layer film may be non-continuous (i.e., discontinuous or partial discontinuous). As used herein the terms "discontinuous bonding" or "discontinuous lamination" refers to lamination of two or more layers where the lamination is not continuous in the machine direction and not continuous in the transverse direction. More particularly, discontinuous lamination refers to lamination of two or more layers with repeating bonded patterns broken up by repeating un-bonded areas in both the machine direction and the transverse direction of the film.

As used herein the terms "partially discontinuous bonding" or "partially discontinuous lamination" refers to lamination of two or more layers where the lamination is substantially continuous in the machine direction or in the transverse direction, but not continuous in the other of the machine direction or the transverse direction. Alternately, partially discontinuous lamination refers to lamination of two or more layers where the lamination is substantially continuous in the width of the article but not continuous in the height of the article, or substantially continuous in the height of the article but not continuous in the width of the article. More particularly, partially discontinuous lamination refers to lamination of two or more layers with repeating bonded patterns broken up by repeating unbounded areas in either the machine direction or the transverse direction.

As used herein, the term "flexible" refers to materials that are capable of being flexed or bent, especially repeatedly, such that they are pliant and yieldable in response to externally applied forces. Accordingly, "flexible" is substantially opposite in meaning to the terms inflexible, rigid, or unyielding. Materials and structures that are flexible, therefore, may be altered in shape and structure to accommodate external forces and to conform to the shape of objects brought into contact with them without losing their integrity. In accordance with further prior art materials, web materials are provided which exhibit an "elastic-like" behavior in the direction of applied strain without the use of added traditional elastic. As used herein, the term "elastic-like" describes the behavior of web materials which when subjected to an applied strain, the web materials extend in the direction of applied strain, and when the applied strain is released the web materials return, to a degree, to their pre-strained condition.

As used herein, the term "starting gauge" or "initial gauge" refers to the average distance between the major surfaces of a film before it is incrementally stretched so as to discontinuously bond adjacent layers together. Of course, it is also possible to stretch one or more of the individual layers before they are discontinuously bonded together.

Methods of providing relatively weak bonding of adjacent layers (i.e., so that the bond strength is less than a weakest tear resistance of the individual layers) can include many techniques, such as adhesive bonding, pressure bonding, ultrasonic bonding, and corona lamination. MD ring rolling, TD ring rolling, or other ring rolling processes (e.g., DD ring rolling or ring rolling that results in a thermoplastic film with strainable networks), and combinations thereof may be used to non-continuously bond adjacent layers of the multilayer film, as will be described in further detail below.

Film Materials

As an initial matter, one or more layers of the films (e.g., **10**-**10***o* of FIGS. **1**A-**9** and **17**B) can comprise any flexible or pliable material comprising a thermoplastic material and that can be formed or drawn into a web or film. As described above, the film includes a plurality of layers of thermoplastic films. Each individual film layer may itself include a single layer or multiple layers. Adjuncts may also be included, as desired (e.g., pigments, slip agents, anti-block agents, tackifiers, or combinations thereof). The thermoplastic material of the films of one or more implementations can include, but are not limited to, thermoplastic polyolefins, including polyethylene, polypropylene, and copolymers thereof. Besides ethylene and propylene, exemplary copolymer olefins include, but are not limited to, ethylene vinylacetate (EVA), ethylene methyl acrylate (EMA) and ethylene acrylic acid (EAA), or blends of such olefins. Various other suitable olefins and polyolefins will be apparent to one of skill in the art.

Other examples of polymers suitable for use as films in accordance with the present invention include elastomeric polymers. Suitable elastomeric polymers may also be biodegradable or environmentally degradable. Suitable elastomeric polymers for the film include poly(ethylene-butene), poly(ethylene-hexene), poly(ethylene-octene), poly(ethylene-propylene), poly(styrene-butadiene-styrene), poly(styrene-isoprene-styrene), poly(styrene-ethylene-butylene-styrene), poly(ester-ether), poly(ether-amide), poly(ethylene-vinylacetate), poly(ethylene-methylacrylate), poly(ethylene-acrylic acid), poly(ethylene butylacrylate), polyurethane, poly(ethylene-propylene-diene), ethylene-propylene rubber, and combinations thereof.

In at least one implementation of the present invention, the film can include linear low density polyethylene. The term "linear low density polyethylene" (LLDPE) as used herein is defined to mean a copolymer of ethylene and a minor amount of an alkene containing 4 to 10 carbon atoms, having a density of from about 0.910 to about 0.926 g/cm$^3$, and a melt index (MI) of from about 0.5 to about 10. For example, one or more implementations of the present invention can use an octene co-monomer, solution phase LLDPE (MI=1.1; ρ=0.920). Additionally, other implementations of the present invention can use a gas phase LLDPE, which is a hexene gas phase LLDPE formulated with slip/AB (MI=1.0; ρ=0.920). One will appreciate that the present invention is not limited to LLDPE, and can include "high density polyethylene" (HDPE), "low density polyethylene" (LDPE), and "very low density polyethylene" (VLDPE). Indeed films made from any of the previously mentioned thermoplastic materials or combinations thereof can be suitable for use with the present invention.

One will appreciate in light of the disclosure herein that manufacturers may form the individual films or webs to be non-continuously bonded together so as to provide improved strength characteristics using a wide variety of techniques. For example, a manufacturer can form a precursor mix of the thermoplastic material including any optional additives. The manufacturer can then form the film(s) from the precursor mix using conventional flat extrusion, cast extrusion, or coextrusion to produce monolayer, bilayer, or multilayered films. In any case, the resulting film will be discontinuously bonded to another film at a later stage to provide the benefits associated with the present invention.

Alternative to conventional flat extrusion or cast extrusion processes, a manufacturer can form the films using other suitable processes, such as, a blown film process to produce monolayer, bilayer, or multilayered films, which are subsequently discontinuously bonded with another film layer at a later stage. If desired for a given end use, the manufacturer can orient the films by trapped bubble, tenterframe, or other suitable processes. Additionally, the manufacturer can optionally anneal the films.

The extruder used can be of a conventional design using a die, which will provide the desired gauge. Some useful extruders are described in U.S. Pat. Nos. 4,814,135; 4,857,600; 5,076,988; 5,153,382; each of which are incorporated herein by reference in their entirety. Examples of various extruders, which can be used in producing the films to be used with the present invention, can be a single screw type modified with a blown film die, an air ring, and continuous take off equipment.

In one or more implementations, a manufacturer can use multiple extruders to supply different melt streams, which a feed block can order into different channels of a multichannel die. The multiple extruders can allow a manufacturer to form a multi-layered film with layers having different compositions. Such multi-layer film may later be non-continuously laminated with another layer of film to provide the benefits of the present invention.

In a blown film process, the die can be an upright cylinder with a circular opening. Rollers can pull molten plastic upward away from the die. An air-ring can cool the film as the film travels upwards. An air outlet can force compressed air into the center of the extruded circular profile, creating a bubble. The air can expand the extruded circular cross section by a multiple of the die diameter. This ratio is called the "blow-up ratio." When using a blown film process, the manufacturer can collapse the film to double the plies of the film. Alternatively, the manufacturer can cut and fold the film, or cut and leave the film unfolded.

The films of one or more implementations of the present invention can have a starting gauge between about 0.1 mils to about 20 mils, suitably from about 0.2 mils to about 4 mils, suitably in the range of about 0.3 mils to about 2 mils, suitably from about 0.6 mils to about 1.25 mils, suitably from about 0.9 mils to about 1.1 mils, suitably from about 0.3 mils to about 0.7 mils, and suitably from about 0.4 mils and about 0.6 mils. Additionally, the starting gauge of films of one or more implementations of the present invention may not be uniform. Thus, the starting gauge of films of one or more implementations of the present invention may vary along the length and/or width of the film.

As previously mentioned, according to one implementation of the invention, the separate layers of the multi-layer film are non-continuously, lightly bonded to one another. FIGS. **1A-1C** illustrate exemplary processes of partially discontinuously bonding adjacent layers of a multi-layer thermoplastic film in accordance with an implementation of the present invention. In particular, FIGS. **1A-1C** illustrate an MD ring rolling process that partially discontinuously laminates the individual adjacent layers of thermoplastic multi-layered film **10** by passing the multi-layered film **10** through a pair of MD intermeshing rollers **12**, **14**. As a result of MD ring rolling, the multi-layered film **10** is also intermittently stretched in the machine direction MD.

As shown by the FIGS. **1A-1C**, the first roller **12** and the second roller **14** can each have a generally cylindrical shape. The rollers **12**, **14** may be made of cast and/or machined metal, such as, steel, aluminum, or any other suitable material. The rollers **12**, **14** can rotate in opposite directions about parallel axes of rotation. For example, FIG. **1A** illustrates that the first roller **12** can rotate about a first axis **16** of rotation in a counterclockwise direction **18**. FIG. **1A** also illustrates that the second roller **14** can rotate about a second axis **20** of rotation in a clockwise direction **22**. The axes of rotation **16**, **20** can be parallel to the transverse direction TD and perpendicular to the machine direction MD.

The intermeshing rollers **12**, **14** can closely resemble fine pitch spur gears. In particular, the rollers **12**, **14** can include a plurality of protruding ridges **24**, **26**. The ridges **24**, **26** can extend along the rollers **12**, **14** in a direction generally parallel to axes of rotation **16**, **20**. Furthermore, the ridges **24**, **26** can extend generally radially outward from the axes of rotation **16**, **20**. The tips of ridges **24**, **26** can have a variety of different shapes and configurations. For example, the tips of the ridges **24**, **26** can have a rounded shape as shown in FIGS. **1B-1C**. In alternative implementations, the tips of the ridges **24**, **26** can have sharp angled corners. FIGS. **1A-1C** also illustrate that grooves **28**, **30** can separate adjacent ridges **24**, **26**.

The ridges **24** on the first roller **12** can be offset or staggered with respect to the ridges **26** on the second roller **14**. Thus, the grooves **28** of the first roller **12** can receive the ridges **26** of the second roller **14**, as the rollers **12**, **14** intermesh. Similarly, the grooves **30** of the second roller **14** can receive the ridges **24** of the first roller **12**.

One will appreciate in light of the disclosure herein that the configuration of the ridges **24**, **26** and grooves **28**, **30** can prevent contact between ridges **24**, **26** during intermeshing so that no rotational torque is transmitted during operation. Additionally, the configuration of the ridges **24**, **26** and grooves **28**, **30** can affect the amount of stretching and the bond strength resulting from partially discontinuous lamination as the film passes through intermeshing rollers **12**, **14**.

Referring specifically to FIGS. **1B-1C**, various features of the ridges **24**, **26** and grooves **28**, **30** are shown in greater detail. The pitch and depth of engagement of the ridges **24**, **26** can determine, at least in part, the amount of incremental stretching and partially discontinuous lamination caused by the intermeshing rollers **12**, **14**. As shown by FIGS. **1B-1C**, the pitch **32** is the distance between the tips of two adjacent ridges on the same roller. The "depth of engagement" ("DOE") **34** is the amount of overlap between ridges **24**, **26** of the different rollers **12**, **14** during intermeshing.

The ratio of DOE **34** to pitch **32** can determine, at least in part, the bond strength provided by the partially discontinuous bonding. According to one embodiment, the ratio of DOE to pitch provided by any ring rolling operation is less than about 1.1:1, suitably less than about 1.0:1, suitably between about 0.5:1 and about 1.0:1, or suitably between about 0.8:1 and about 0.9:1.

As shown by FIG. **1A**, the direction of travel of the multi-layered film **10** through the intermeshing rollers **12**, **14** is parallel to the machine direction and perpendicular to the transverse direction. As the thermoplastic multi-layered film **10** passes between the intermeshing rollers **12**, **14**, the ridges **24**, **26** can incrementally stretch the multi-layered film **10** in the machine direction. In one or more implementations, stretching the multi-layered film **10** in the machine direction can reduce the gauge of the film and increase the length of the multi-layered film **10**. In other implementations, the multi-layered film **10** may rebound after stretching such that the gauge of the multi-layered film **10** is not decreased. Furthermore, in one or more implementations, stretching the film **10** in the machine direction can reduce the width of the multi-layered film **10**. For example, as the multi-layered film **10** is lengthened in the machine direction, the film's length can be reduced in the transverse direction.

In particular, as the multi-layered film **10** proceeds between the intermeshing rollers **12**, **14**, the ridges **24** of the first roller **12** can push the multi-layered film **10** into the grooves **30** of the second roller **14** and vice versa. The pulling of the multi-layered film **10** by the ridges **24**, **26** can stretch the multi-layered film **10**. The rollers **12**, **14** may not stretch the multi-layered film **10** evenly along its length. Specifically, the rollers **12**, **14** can stretch the portions of the film **10** between the ridges **24**, **26** more than the portions of the multi-layered film **10** that contact the ridges **24**, **26**. Thus, the rollers **12**, **14** can impart or form a generally striped pattern **36** into the multi-layered film **10**. As used herein, the terms "impart" and "form" refer to the creation of a desired structure or geometry in a film upon stretching the film that will at least partially retain the desired structure or geometry when the film is no longer subject to any strains or externally applied forces.

FIGS. **1A-1C** illustrate that the film **10***a* (i.e., the film that is yet to pass through the intermeshing rollers **12**, **14**) can have a substantially flat top surface **38** and substantially flat bottom surface **40**. As seen in FIG. **1**B, the multi-layer film **10***a* may comprise two layers **10***c* and **10***d* that are initially separate from one another. The film **10***a* can have an initial thickness or starting gauge **42** (i.e., the sum of **42***a* and **42***b*) extending between its major surfaces (i.e., the top surface **38** and the bottom surface **40**). In at least one implementation, the starting gauge **42**, as well as the gauge **42***a*, **42***b* of individual layers **10***c* and **10***d* can be substantially uniform along the length of the multi-layer film **10***a*. Because the inner surfaces of each layer **10***c* and **10***d* are somewhat tacky, the layers become lightly bonded together as they are pulled through and stretched by intermeshing rollers **12**, **14**. Those areas that are stretched become lightly bonded together.

In one or more implementations, the pre-laminated film **10***a* need not have an entirely flat top surface **38**, but may be rough or uneven. Similarly, bottom surface **40** or the inner oriented surfaces of layers **10***c* and **10***d* of the film **10***a* can also be rough or uneven. Further, the starting gauge **42**, **42***a*, and **42***b* need not be consistent or uniform throughout the entirety of pre-stretched film **10***a*. Thus, the starting gauge **42**, **42***a*, and **42***b* can vary due to product design, manufacturing defects, tolerances, or other processing issues. According to one embodiment, the individual layers **10***c* and **10***d* may be pre-stretched (e.g., through MD ring rolling, TD ring rolling, etc.) before being positioned adjacent to the other layer (**10***d* or **10***c*, respectively). Such pre-stretching of individual layers can result in a striped surface exhibiting an uneven top and bottom surface similar to that seen in FIG. **1**A.

FIG. **1**B illustrates that films **10***a*, can include two initially separate film layers **10***c*-**10***d*. FIG. **1**C illustrates an alternative implementation where film **10***a*' (and thus the incrementally stretched film **10***i*) can include three initially separate film layers: a middle film layer **10***g*, and two outer film layers **10***f*, **10***h*. In other embodiments, more than 3 layers may be provided (four, five, six, or more partially discontinuously or discontinuously laminated layers).

As seen in FIG. **1**A, upon stretching and partially discontinuous lamination of the adjacent layers, the multi-layered lightly-laminated film **10***b* of FIG. **1**A, **10***e* of FIG. **1**B, or film **10***i* of FIG. **1**C can include a striped pattern **36**. The striped pattern **36** can include alternating series of un-bonded and un-stretched regions **44** adjacent to bonded and stretched regions **46**. FIGS. **1**B and **1**C illustrate that the intermeshing rollers **12**, **14** can incrementally stretch and partially discontinuously bond films **10***a*, **10***a*' to create multi-layered lightly-laminated multi-layer films **10***b*, **10***e*, **10***i* including bonded regions **46** and un-bonded regions **44**.

For example, FIG. **1**B illustrates that the film layers **11***a*, **11***b* of the multi-layered lightly-laminated film **10***e* can be laminated together at the stretched regions **46**, while the un-stretched regions **44** may not be laminated together. Similarly, FIG. **1**C illustrates that the film layers **11***c*, **11***d*, **11***e* of the multi-layered lightly-laminated **10***i* can be laminated together at the stretched regions **46**, while the un-stretched regions **44** may not be laminated together.

In addition to any compositional differences between layers **10***c*, **10***d*, **10***f*, **10***g*, or **10***h* of a given multi-layer film, the different film layers can have differing gauges or thicknesses. In one or more implementations, the film layers may be substantially equal to one another in thickness. For example, the inventors have found that the MD or TD tear resistance of the composite, multi-layer film is typically approximately equal to the lowest MD or TD tear value of the individual layers, absent any increase in tear resistance provided by light bonding. In other words, the weakest layer often determines the strength of the multi-layer film structure.

As shown by FIGS. **1**B and **1**C the un-bonded regions **44** of the multi-layered lightly-laminated films **10***e*, **10***i*, can have a first average thickness or gauge **48***a*, **48***b*, respectively. The first average gauge **48***a*, **48***b* can be approximately equal to the combined starting gauges **42***a-b*, **42***c-e* of the starting films. In the Figures, separation between the unbonded layers at regions **44** is exaggerated for purposes of clarity. In one or more implementations, the first average gauge **48***a*, **48***b* can be less than the combined starting gauges **42***a*-**42***b*, **42***c*-**42***e*. The lightly bonded regions **46** can have a second average thickness or gauge **50***a*, **50***b*. In one or more implementations, the second average gauge **50***a*, **50***b* can be less than the combined starting gauges **42***a*-**42***b*, **42***c*-**42***e* and the first average gauge **48***a*, **48***b*, respectively.

In any event, FIGS. **1**A-**1**C illustrate that intermeshing rollers **12**, **14** can process the initially separately layered films into MD incrementally-stretched multi-layered lightly-laminated films. As previously mentioned, the MD incrementally-stretched multi-layered lightly-laminated films can include a striped pattern **36** where the bonding occurs along a continuous line or region along the width of the film **10***b*, parallel to the TD direction. The striped pattern **36** can include alternating series of un-bonded, un-stretched regions **44** and bonded, stretched regions **46**. Although the un-stretched regions of the multi-layered lightly-laminated films may be stretched to a small degree by rollers **12**, **14** (or stretched in a separate operation), the un-stretched regions may be stretched significantly less compared to the bonded, stretched regions **46**.

FIG. **2** illustrates a top view of the MD incrementally-stretched multi-layered lightly-laminated film **10***b* with adjacent bonded and unbonded regions. As shown by FIG. **2**, the film **10***b* includes bonded, stretched regions **46** adjacent to un-bonded, un-stretched regions **44**. In addition to resulting in partially discontinuous lamination of adjacent layers, MD ring rolling the film **10** can increase or otherwise modify one or more of the tensile strength, tear resistance, impact resistance, or elasticity of the film **10***b*, in addition to whatever additional strength is provided by the partially discontinuous, low strength bonds between adjacent layers of the film. Such bonds can be broken to absorb forces rather than such forces resulting in tearing of the film.

Furthermore, the bonded, stretched regions **46** can include bonded stripes that extend across the film **10***b* in a direction transverse (i.e., transverse direction) to a direction in which the film was extruded (i.e., machine direction). As shown by FIG. **2**, the bonded stripes or stretched regions **46** can extend across the entire length of the film **10***b*. One will appreciate in light of the disclosure herein that the striped pattern **36** may vary depending on the method used to incrementally stretch and partially discontinuously bond adjacent layers of film **10**. To the extent that MD or other ring rolling is used to lightly bond the film **10**, the striped pattern **36** (e.g., width and spacing of the stripes or stretched regions **46**) on the film **10** can depend on the pitch **32** of the ridges **24**, **26**, the DOE **34**, and other factors. As regions **46** represent areas of the multi-layer film in which the adjacent layers are lightly bonded to one another, it will be apparent that altering the spacing and/or width of regions **46** can affect the overall strength of the film. For example, providing more bonded surface area relative to the unbonded surface area can increase the density of such bonds that can absorb forces, increasing the film strength.

FIG. **2** further illustrates that the bonded regions **46** can be intermittently dispersed about un-bonded regions **44**. In particular, each bonded region **46** can reside between adjacent un-bonded regions **44**. Additionally, the bonded regions **46** can be visually distinct from the un-bonded regions **44** as a result of stretching. The striped pattern **36** may vary depending on the method used to lightly laminate the film **10**. In one or more implementations, the molecular structure of the thermoplastic material of the film multi-layered **10** may be rearranged during stretching (e.g., particularly so during cold stretching).

MD ring rolling is one exemplary method of partially discontinuously laminating a multi-layer film by incremental stretching of the film. TD ring rolling is another suitable method of discontinuously or partially discontinuously laminating a film. For example, FIG. **3** illustrates a TD ring rolling process that partially discontinuously and lightly bonds adjacent layers of a thermoplastic multi-layer film **10** by passing the film **10** through a pair of TD intermeshing rollers **52**, **54**.

A TD ring rolling process (and associated TD intermeshing rollers **52**, **54**) can be similar to the MD ring rolling process (and associated MD intermeshing rollers **12**, **14**) described herein above, except that the ridges **56**, **58** and grooves **60**, **62** of the TD intermeshing rollers **52**, **54** extend generally orthogonally to the axes of rotation **16**, **20** (i.e., parallel to the MD direction). Thus, as shown by FIG. **3**, as the thermoplastic film **10** passes between the intermeshing rollers **52**, **54**, the ridges **56**, **58** can incrementally stretch and lightly bond adjacent layers of the multi-layer film **10**. The resultant multi-layered lightly-laminated film **10*j*** can include a striped pattern **36*a*** within the width of adjacent bonded and unbonded regions.

FIG. **4** illustrates a view of the TD incrementally-stretched multi-layered lightly-laminated film **10*j*** with bonded regions **46*a*** and adjacent un-bonded regions **44*a***. The striped pattern **36*a*** can include alternating series of un-bonded regions **44*a*** and bonded regions **46*a***. Similar to MD ring rolling, TD ring rolling the multi-layered film **10** can result in relatively light, partially discontinuous bonding of adjacent layers **10*c***, **10*d*** (or **10*f***, **10*g***, **10*h***), increasing the strength of the multi-layer film **10*j***.

FIG. **4** illustrates that the bonded regions **46*a*** can include stripes that extend across the multi-layered lightly-laminated film **10*j*** in the machine direction. As shown by FIG. **4**, the stripes or bonded regions **46*a*** can extend across the entire width of the multi-layered lightly-laminated film **10*j***. In alternative implementations, bonded regions **46*a*** can extend across only a portion of the multi-layered lightly-laminated film **10*j***. Similar to MD ring rolling, the pitch and the DOE of the ridges **56**, **58** of the intermeshing rollers **52**, **54** can affect the width and spacing of the stripes or bonded regions **46*a***, as well as the strength of the light bonds formed between adjacent layers, thereby affecting the overall increase in strength provided by the processing.

In still further implementations, a multi-layered film **10** can undergo both an MD ring rolling process and a TD ring rolling process to lightly bond the individual layers together. For example, FIG. **5** illustrates a top view of a multi-layered lightly-laminated film **10*k*** with bonded, stretched regions separated by un-bonded, un-stretched regions created by MD and TD ring rolling. The multi-layered lightly-laminated film **10*k*** can have a grid pattern **36*b*** including alternating series of un-bonded regions **44*b*** and bonded regions **46*b***, **46*c***. In particular, un-bonded regions **44*b*** may comprise a plurality of discrete squares or rectangles while the remainder of the surface comprises a grid of horizontal and vertical bonded regions that are connected together. The bonded regions **46*b***, **46*c*** can include stripes **46*b*** that extend along the multi-layered lightly-laminated film **10*k*** in the machine direction, and stripes **46*c*** that extend along the film in the transverse direction, which cross each other. As shown by FIG. **5**, in one or more implementations, the aspect ratio of the rows and columns of the bonded regions **46*b***, **46*c*** can be approximately 1 to 1. In alternative implementations, the aspect ratio of the rows and columns of bonded regions **46*b***, **46*c*** can be greater or less than 1 to 1, for example, as explained in greater detail in relation to FIG. **13**.

The multi-layered lightly-laminated film **10*k*** with bonded regions and adjacent un-bonded regions created by MD and TD ring rolling can allow for greater material savings by further increasing the surface area of a given portion of film, by increasing the density of light lamination bonds within a given area, and may also provide properties or advantages not obtained by MD or TD ring rolling alone.

In yet further implementations, a manufacturer can use DD ring rolling to lightly bond a thermoplastic film. DD ring rolling processes (and associated DD intermeshing rollers) can be similar to the MD ring rolling process (and associated MD intermeshing rollers **12**, **14**) described herein above, except that the ridges and grooves of the DD intermeshing rollers can extend at an angle relative to the axes of rotation. For example, FIG. **6** illustrates a view of multi-layered lightly-laminated film **101** with bonded regions created by DD ring rolling. The multi-layered lightly-laminated film **101** can have a diamond pattern **36*c***. The diamond pattern **36*c*** can include alternating series of diamond-shaped un-bonded regions **44*c*** and bonded regions **46*d***. The bonded regions can include stripes **46*d*** oriented at an angle relative to the transverse direction such that the stripes **46*d*** are neither parallel to the transverse or machine direction. The illustrated configuration may be achieved with two ring rolling operations, similar to that of FIG. **5**, but in which the DD ring rollers of each operation are angularly offset relative to one another (e.g., one providing an angle of about 45° off of MD ring rolling, the other providing an angle of about 45° off of TD ring rolling).

In accordance with another implementation, a structural elastic like film (SELF) process may be used to create a thermoplastic film with strainable networks, which similarly results in discontinuous bonding of adjacent layers within a multi-layer film. As explained in greater detail below, the strainable networks can include adjacent bonded and un-bonded regions. U.S. Pat. Nos. 5,518,801; 6,139,185; 6,150,647; 6,394,651; 6,394,652; 6,513,975; 6,695,476; U.S. Patent Application Publication No. 2004/0134923; and U.S. Patent Application Publication No. 2006/0093766 each disclose processes for forming strainable networks or patterns of strainable networks suitable for use with implementations of the present invention. The contents of each of the aforementioned patents and publications are incorporated in their entirety by reference herein.

FIG. **7** illustrates a pair of SELF'ing intermeshing rollers **72**, **74** for creating strainable networks with lightly bonded regions in a film. The first SELF'ing intermeshing roller **72** can include a plurality of ridges **76** and grooves **78** extending generally radially outward in a direction orthogonal to an axis of rotation **16**. Thus, the first SELF'ing intermeshing roller **72** can be similar to a TD intermeshing roller **52**, **54**. The second SELF'ing intermeshing roller **74** can include also include a plurality of ridges **80** and grooves **82** extending generally radially outward in a direction orthogonal to an axis of rotation **20**. As shown by FIG. **7**, however, the ridges

80 of the second SELF'ing intermeshing roller 74 can include a plurality of notches 84 that define a plurality of spaced teeth 86.

Referring now to FIG. 8, a multi-layered lightly-laminated film 10*m* with bonded regions dispersed about un-bonded regions created using the SELF'ing intermeshing rollers 72, 74 is shown. In particular, as the film passes through the SELF'ing intermeshing rollers 72, 74, the teeth 86 can press a portion of the multi-layer web or film out of plane to cause permanent deformation of a portion of the film in the Z-direction. The portions of the film that pass between the notched regions 84 of the teeth 86 will be substantially unformed in the Z-direction, resulting in a plurality of deformed, raised, rib-like elements 88. The length and width of rib-like elements 88 depends on the length and width of teeth 86.

As shown by FIG. 8, the strainable network of the multi-layered lightly-laminated film 10*m* can include first un-bonded regions 44*d*, second un-bonded regions 44*e*, and bonded transitional regions 46*e* connecting the first and second un-bonded regions 44*d*, 44*e*. The second un-bonded regions 44*e* and the bonded regions 46*e* can form the raised rib-like elements 88 of the strainable network. The bonded regions 46*e* can be discontinuous or separated as they extend across the multi-layered film 10*m* in both transverse and machine directions. This is in contrast to stripes that extend continuously across a film in one of the machine or transverse directions.

The rib-like elements 88 can allow the multi-layered lightly-laminated film 10*m* to undergo a substantially "geometric deformation" prior to a "molecular-level deformation" or a "macro-level deformation." As used herein, the term "molecular-level deformation" refers to deformation which occurs on a molecular level and is not discernible to the normal naked eye. That is, even though one may be able to discern the effect of molecular-level deformation, e.g., macro-level deformation of the film, one is not able to discern the deformation which allows or causes it to happen. As used herein, the term "macro-level deformation" refers to the effects of "molecular-level deformation," such as stretching, tearing, puncturing, etc. In contrast, the term "geometric deformation," which refers to deformations of multi-layered lightly-laminated film 10*m* which are generally discernible to the normal naked eye, but do not cause the molecular-level deformation when the multi-layered film 10*m* or articles embodying the multi-layered lightly-laminated film 10*m* are subjected to an applied strain. Types of geometric deformation include, but are not limited to bending, unfolding, and rotating.

Thus, upon application of strain, the rib-like elements 88 can undergo geometric deformation before either the rib-like elements 88 or the flat regions undergo molecular-level deformation. For example, an applied strain can pull the rib-like elements 88 back into plane with the flat regions prior to any molecular-level deformation of the multi-layered film 10*m*. Geometric deformation can result in significantly less resistive forces to an applied strain than that exhibited by molecular-level deformation.

In addition to improved properties thus provided by the ability to geometrically deform, the SELF'ing process also discontinuously and lightly laminates adjacent layers of the multi-layer film together, providing the benefits noted above. In particularly, the film layers 11*f*, 11*g* can be lightly laminated at stretched regions 46*e*, but un-bonded at the un-stretched regions 44*d* and 44*e*. The strength of the lamination bond is relatively weak, so as to be less than the weakest tear resistance of the individual layers of the multi-layer film. Thus, the lamination bond is broken rather than the individual layer tearing upon application of a force. Typically, tearing in the MD direction requires less applied force than tearing in the TD direction, thus in one embodiment, the lamination bond strength is less than the MD tear resistance of each individual layer of the multi-layer film.

FIG. 9 illustrates a multi-layered lightly-laminated film 10*n* with a strainable network of rib-like elements 88*a* arranged in diamond patterns. The strainable network of the multi-layered lightly-laminated film 10*n* can include first un-bonded regions 44*d*, second un-bonded regions 44*e*, and bonded transitional regions 46*e* connecting the first and second un-bonded regions 44*d*, 44*e*.

One or more implementations of the present invention can include strainable network patterns other than those shown by FIGS. 8 and 9, or combinations of various patterns. It should be understood that the term "pattern" is intended to include continuous or discontinuous sections of patterns, such as may result, for example, from the intersection of first and second patterns with each other. Furthermore, the patterns can be aligned in columns and rows aligned in the machine direction, the transverse direction, or neither the machine or transverse directions.

For example, FIGS. 10A and 10B show a multi-layered lightly-laminated film 10*o* where the film layers have undergone a film stretching process in which a discontinuous laminate material is formed with a strainable network of distinct regions. The strainable network laminate includes a plurality of un-bonded areas 146 that define a first region and a plurality of bonded areas 148 that define a second region. Portions of the un-bonded areas 146, indicated generally as 147, extend in a first direction and may be substantially linear. Remaining portions of the unbonded areas 146, indicated generally as 145, extend in a second direction that is substantially perpendicular to the first direction, and the remaining portions 145 of the unbonded areas 146 may be substantially linear. While it may be preferred that the first direction be perpendicular to the second direction, other angular relationships between the first direction and the second direction may be suitable. The angles between the first and second directions may range from about 45° to about 135°, with 90° being the most preferred. Intersecting sections of the portions 147 and 145 of the unbonded areas 146 form boundaries 150 (only one shown in FIG. 10A), which completely surround the bonded areas 148. It should be understood that the boundaries 150 are not limited to the square shape illustrated herein and that boundaries 150 may comprise other shapes as required by the particular configuration of the un-bonded and bonded areas 146, 148, respectively.

The multi-layered lightly-laminated multi-layer film 10*o* shown in FIG. 10A-10B comprises a multi-directional strainable network laminate providing stretch characteristics in multiple directions of strain, similar to that shown in FIG. 8. A first region comprises un-bonded areas 146 generally illustrated as bands of unformed material generally lying in a plane defined by the discontinuous laminate material 100. A second region comprises bonded areas 148 generally defined by nub-like patterns 152 (see FIG. 10B) extending out of the plane of the discontinuous laminate material 10*o* and comprised of a pattern extending in first and second distinct directions as formed by first and second superimposed patterns, where the patterns are illustrated as being substantially similar to each other.

FIGS. 11A-11B illustrate an embossing type roll configuration for lightly bonding layers together by forming a multi-directional strainable network laminate in a single pass through a set of intermeshing rollers including a punch roll **153** and a cooperating die roll **154**, where the punch roll is provided with punch regions **156** and the die roll is provided with corresponding die regions **158** for cooperating with the punch regions **156**. The punch regions **156** may each be provided with a plurality of punch elements **160** for cooperating with corresponding die elements **162** in the die regions **158**. Cooperating engagement of the punch elements **160** with the die elements **162**, with a sheet material therebetween, forms a bonded pattern on the material. Alternatively, the cooperating die roll **154** may comprise a conformable surface for conforming to the punch elements **160**, or other surface configuration of the punch roll **153**.

Referring to FIG. **11**C, a pattern formed by the rolls **153**, **154** is illustrated in which each of the bonded areas **148** of the multi-directional strainable network laminate is formed by a cooperating set of punch and die elements **160**, **162**, such as is illustrated in the enlarged surface views of FIG. **22**B, and the remaining unformed areas define the unbonded areas **146** of the multi-layered lightly-laminated film including multi-directional strainable networks.

One will appreciate in light of the disclosure herein that using ring rolling and/or SELFing to form the light bonds can provide the additional benefit of stretching the film layers, thereby reducing the basis weight of the multi-layered lightly-laminated film. Thus, using incremental stretching to form the light bonds can allow for multi-layer films at a lower basis weight (amount of raw material) to perform the same as or better than higher basis weight mono-layer or co-extruded films.

In addition to ring rolling and SELFing, one or more implementations include using embossing, stamping, adhesive lamination, ultrasonic bonding, or other methods of lightly laminating layers of a multilayer film. In such implementations, one or more of the layers of the multi-layered lightly-laminated film can be stretched to reduce the basis weight and/or modify the strength parameters of the film prior to lamination. Stretching of the individual layers can include incrementally-stretching (e.g., ring rolling, SELFing) or continuous stretching (e.g., MDO).

One will appreciate in light of the disclosure herein that the lightly bonded multi-layered films can form part of any type of product made from, or incorporating, thermoplastic films. For instance, grocery bags, trash bags, sacks, packaging materials, feminine hygiene products, baby diapers, adult incontinence products, sanitary napkins, bandages, food storage bags, food storage containers, thermal heat wraps, facial masks, wipes, hard surface cleaners, and many other products can include lightly bonded multi-layer films to one extent or another. Trash bags and food storage bags may be particularly benefited by the films and methods of the present invention.

Referring to FIGS. **12**A and **12**B, the multi-layer film **10***j* illustrated in FIG. **4** is incorporated in a flexible draw tape bag **90**. The bag **90** can include a bag body **92** formed from a piece of incrementally-stretched adhesively-laminated film **10***j* folded upon itself along a bag bottom **94**. Side seams **96** and **98** can bond the sides of the bag body **92** together to form a semi-enclosed container having an opening **100** along an upper edge **102**. The bag **90** also optionally includes closure means **104** located adjacent to the upper edge **102** for sealing the top of the bag **90** to form a fully-enclosed container or vessel. The bag **90** is suitable for containing and protecting a wide variety of materials and/or objects. The closure means **104** can comprise flaps, adhesive tapes, a tuck and fold closure, an interlocking closure, a slider closure, a zipper closure or other closure structures known to those skilled in the art for closing a bag.

As shown, the sides of the bag body **92** can include un-stretched regions **44***a* and stretched regions **46***a* in the form of stripes. The stripes can extend across the multi-layered bag **90** in the MD direction, or in other words, from the first side seam **96** to the second side seam **98**. The multi-layered bag **90** can require less material to form than an identical bag formed with film **10***a* (not discontinuously laminated) of the same thermoplastic material. Additionally, despite requiring less material, the multi-layered bag **90** includes improved strength properties imparted by lightly bonding adjacent layers of the multi-layer film together.

Furthermore, as shown by FIGS. **12**A and **12**B, a bag **90** formed from a multi-layered lightly-laminated film can have a first layer of thermoplastic material (i.e., film **10***j*). The first layer (i.e., film **10***j*) can include first and second side walls joined along a bottom edge, a first side edge, and an opposing second side edge. In particular, the bottom edge of the first layer (i.e., film **10***j*) can comprise a fold. The bag **90** can also include a second layer of thermoplastic material (i.e., film **10***j*'). The second layer (i.e., film **10***j*') can include first and second side walls joined along a bottom edge, a first side edge, and an opposing second side edge.

As shown by FIG. **12**B, the second layer (i.e., film **10***j*') is positioned within the first layer (i.e., film **10***j*). Furthermore, the first layer (i.e., film **10***j*) and the second layer (i.e., film **10***j*') are non-continuously bonded to each other. Furthermore, in the implementation shown in FIGS. **12**A and **12**B, both the first layer (i.e., film **10***j*) and the second layer (i.e., film **10***j*') are incrementally stretched.

Such a configuration may be considered a "bag-in-bag" configuration. In other words the bag **90** can include a second thermoplastic bag **10***j*' positioned within a first thermoplastic bag **10***j*. Each of the first and second bags **10***j*, **10***j*' can include a first pair of opposing sidewalls joined together along three edges. A plurality of non-continuous bonded regions **44***a* can secure the first and second thermoplastic bags together.

Although illustrated with a particular ring rolled pattern, it will be understood that other techniques as described herein may be used to non-continuously laminate the inner bag to the outer bag. For example, the bonded regions may also or alternatively be formed through the use of TD ring rolling, DD, ring rolling, SELFing, ultrasonic bonding, adhesive bonding, or any combination of such various bonding techniques.

FIG. **13** illustrates a multi-layered tie bag **106** incorporating a multi-layered lightly-laminated film in accordance with an implementation of the present invention. As shown, the sides of the tie bag **106** can include a pattern of un-bonded, regions **44***f* and bonded regions **46***f*, **46***g* created by MD and TD ring rolling.

The lightly bonded regions can include stripes **46***f* that extend across the bag **106** in the machine direction. Additionally, the bonded regions can include stripes **46***g* that extend across the bag **106** in the transverse direction, or in other words from the bag bottom **108** to flaps **110** of an upper edge **112** of the multi-layered bag **106**. Bonded regions **46***f* and **46***g* are characterized by relatively light bonding of adjacent layers of the multi-layer film, which acts to absorb forces into breaking of the lamination bond rather than allowing that same force to cause tearing of either of the layers of the multi-layer film. Such action provides significantly increased strength to the multi-layer film as compared to a monolayer similar thickness film or compared to a multi-layer film of similar thickness where the layers are strongly bonded together (i.e., at a bond strength at least as great as the tear resistance of the weakest layer). The lamination bond includes a bond strength that is advantageously less than the tear resistance of each of the individual films so as to cause the lamination bond to fail prior to tearing of the film layers.

In comparison with the film **10***k* of FIG. **5**, the spacing between the MD extending stripes **46***f* is greater in the multi-layered bag **106**. This effect is created by using MD ring rolls having a greater pitch between ridges. Similarly, the spacing of the TD extending stripes **46***g* is greater in the multi-layered bag **106** than the multi-layered film **10***m*. This effect is created by using TD ring rolls having a greater pitch between ridges. Furthermore, the relative spacing between the MD extending stripes and the TD extending stripes differs in the multi-layered bag **106**, while relative spacing is the same in the multi-layered film **10***k*. This effect is created by using TD ring rolls having a greater pitch between ridges compared to the pitch between ridges of the MD ring rolls.

One will appreciate in light of the disclosure herein that the use of intermeshing rollers with greater or varied ridge pitch can provide the different spacing and thicknesses of the stripes. Thus, a manufacturer can vary the ridge pitch of the intermeshing rollers to vary the pattern of the multi-layer film. The bond density (i.e., the fraction of surface area that is bonded relative to unbonded) and particular pattern provided not only affects the aesthetic appearance of the bag or film, but may also affect the strength characteristics provided. For example, higher bond density may provide increased strength as it provides a greater number of relatively low strength lamination bonds that may be broken so as to absorb forces, preventing such forces from leading to tearing of the bag or film. Film **10***k* of FIG. **5** has a higher bond density than the film of the bag **106** of FIG. **13**.

By way of further example, where the MD tear resistance is lower than TD tear resistance for the particular films employed, it may be advantageous to provide a higher density of bonds in the MD than the TD direction. This may provide greater improvement to MD tear resistance of the multi-layered lightly-laminated film as compared to TD tear resistance improvement. A similar configuration could be provided for films in which the TD tear resistance were lower than MD tear resistance by increasing bond density in the TD direction.

In addition to varying the pattern of bonded and un-bonded regions in a bag or film, one or more implementations also include providing lightly bonded regions in certain sections of a bag or film, and only un-bonded (or alternatively tightly bonded) regions in other sections of the bag or film. For example, FIG. **14** illustrates a multi-layered bag **114** having an upper section **116** adjacent a top edge **118** that is devoid of bonded regions. Similarly, the multi-layered bag **114** includes a bottom section **120** adjacent a bottom fold or edge **122** devoid of bonded regions. In other words, both the top section **116** and bottom section **120** of the multi-layered bag **114** can each consist only of un-bonded regions. Alternatively, the layers of sections **116** and **120** may be tightly bonded together (e.g., co-extruded). In any case, sections **116** and **120** may be void of bonds.

A middle section **124** of the multi-layered bag **114** between the upper and lower sections **116**, **120** on the other hand can include lightly bonded regions interspersed with un-bonded regions. In particular, FIG. **14** illustrates that the middle section can include a strainable network of rib-like elements arranged in diamond patterns similar to the multi-layered lightly-laminated film **10***n* of FIG. **9**. Thus, the middle section **124** of the multi-layered bag **114** can include improved strength created by the light bonds of the strainable network.

In one or more additional implementations, the present invention includes providing different lightly bonded regions in different sections of a bag or film. For example, FIG. **15** illustrates a multi-layered bag **114***a* similar to the multi-layered bag **114** of FIG. **14**, except that the bottom section **120***a* includes alternating series of un-bonded regions **44***a* and bonded regions **46***a* created by TD ring rolling. Thus, the middle section **124** of the bag **114** can include properties of increased strength as a result of light discontinuous lamination and increased elasticity through geometric deformation, while the bottom section includes increased strength as a result of light partially discontinuous lamination by TD ring rolling.

FIG. **16** illustrates yet another multi-layered bag **126** including an upper section **116***a* adjacent a top edge **118** that includes alternating series of un-bonded regions **44***b* and bonded regions **46***b*, **46***c* created by MD and TD ring rolling similar to the film **10***k* of FIG. **5**. Furthermore, the middle section **124***a* of the multi-layered bag **126** can include un-bonded regions **44** and bonded regions **46** in the form of stripes created by MD ring rolling.

Thus, one will appreciate in light of the disclosure herein that a manufacturer can tailor specific sections or zones of a bag or film with desirable properties by MD, TD, DD ring rolling, SELF'ing, or combinations thereof. One will appreciate in light of the disclosure herein that one or more implementations can include bonded regions arranged in other patterns/shapes. Such additional patterns include, but are not limited to, intermeshing circles, squares, diamonds, hexagons, or other polygons and shapes. Additionally, one or more implementations can include bonded regions arranged in patterns that are combinations of the illustrated and described patterns/shapes.

FIGS. **17**-**25** illustrate additional exemplary implementations of multi-layer bags that may be formed from multi-layered lightly-laminated films. FIGS. **17**-**19** and **25** illustrate additional examples of bags **127** including squares **128**, diamonds **130**, and circles **132** representing the bonded areas of the two or more adjacent layers. In one or more implementations, such as FIGS. **17**-**18** and **23**, each bonded pattern may have a largest TD patterned width **134** in the transverse direction (TD) of less than about 25% of the transverse width **136** of the patterned film, or less than about 20% of the transverse width of the film, or less than about 10% of the transverse width of the patterned film, or less than about 5% of the transverse width of the film. In one or more implementations, the bonded patterns should have a largest MD patterned width **138** in the machine direction of less than about 25% of the machine width **140** of the patterned film, or less than about 20% of the machine width of the film, or less than about 10% of the machine width of the film, or less than about 5% of the transverse width of the film.

In one or more implementations, the width **134** of the bonded patterns in the transverse direction may be greater than the width **142** of the un-bonded areas in the transverse direction. The width **138** of the bonded patterns in the machine direction or direction perpendicular to the transverse direction may be greater than the width of the un-bonded areas **144** in the machine direction.

The bond density of the multi-layered lightly-laminated films and bags incorporating the same can be varied to control the bond strength between the layers. For example, bonded areas of multi-layered lightly-laminated films and bags incorporating the same can be large in comparison to un-bonded areas, as seen in the implementations of FIGS. **17-18** and **25**. For example, bonded areas of multi-layered lightly-laminated films and bags incorporating the same can represent at least about 50% of the total area of the entire film, the entire bag, or the section where the lamination occurs, or at least about 60% of the entire film, the entire bag, or total area of the section where the lamination occurs, at least about 70% of the entire film, the entire bag, or total area of the section where the lamination occurs, at least about 80% of the total area of the entire film, the entire bag, or section where the lamination occurs. In other embodiments, for example in FIGS. **19-20**, the bonded areas of multi-layered lightly-laminated films and bags incorporating the same can represent substantially less than about 50% of the total area of the entire film, the entire bag, or section where the lamination occurs, or less than about 40% of the total area of the entire film, the entire bag, or section where the lamination occurs, or less than about 30% of the total area of the entire film, the entire bag, or section where the lamination occurs, or less than about 10% of the total area of the entire film, the entire bag, or section where the lamination occurs.

As mentioned previously, numerous methods can be used to provide the desired degree of lamination in the bonded areas. Any of the described ring rolling techniques may be combined with other techniques in order to further increase the strength of the lamination bond while maintaining bond strength below the strength of the weakest layer of the multi-layer film. For example, heat, pressure, ultrasonic bonding, corona treatment, or coating (e.g., printing) with adhesives may be employed. Treatment with a corona discharge can enhance any of the above methods by increasing the tackiness of the film surface so as to provide a stronger lamination bond, but which is still weaker than the tear resistance of the individual layers.

Adjusting (e.g., increasing) the strength of the relatively light lamination bonding could be achieved by addition of a tackifier or adhesive to one or more of the skin plies of a multi-layer film, or by incorporating such a component into the material from which the film layer is formed. For example, the outer skin sublayers of a given layer could contain from about 0 to about 50% of a polyolefin plastomer tackifier such as a $C_4$-$C_{10}$ olefin to adjust bonding strength by increasing the tackiness of the surfaces of adjacent layers to be lightly laminated.

In one or more implementations, a component may be included to decrease tackiness. For example, the outer skin sublayers could contain higher levels of slip or anti-block agents, such as talc or oleamide (amide of oleic acid), to decrease tack. Similarly, these surfaces may include very low levels of or be substantially void of slip or anti-block agents to provide a relative increase in tackiness.

FIG. **18** shows a multi-layer bag **127** including a top section that has been both MD and TD ring rolled, while the bottom section has not been discontinuously laminated. FIG. **19** shows a bag **127** including a relatively low density of bonded circles **132** arranged over substantially the entire surface of bag **127**. FIG. **20** shows a bag **127** including an even lower density of bonded diamonds near top and bottom sections of bag **127**. FIG. **21** shows a multi-layer bag **127** that has been ring rolled near the top and bottom of the bag. The middle section of the bag represents an un-bonded region between the ring top and bottom portions of bag **127**. FIG. **22** shows a bag **127** similar to that of FIG. **21** but in which the bottom section is un-bonded. FIG. **23** shows a bag **127** similar to that of FIG. **21**, but in which the top section includes squares of bonded regions rather than being ring rolled. FIG. **24** is similar to the bag of FIG. **20**, but in which the bonded ring rolled portions along the top are discontinuous. FIG. **25** shows a multi-layer bag **127** including top and bottom sections that have been DD ring rolled, while a middle section therebetween has not been discontinuously laminated

In another implementation, a pattern may be formed by embossing, in a process similar to ring rolling. Embossed patterns such as squares, diamonds, circles or other shapes may be embossed into a multi-layer film such as shown in FIGS. **17-20**, and **25**. The embossed, laminated film layers may be prepared by any suitable means by utilizing two or more layers of preformed web of film and passing them between embossing rollers. The method of embossing multiple layers of film can involve calendar embossing two or more separate, non-laminated layers with discrete “icons” to form bonded areas or icons, each icon having a bonded length and separated from adjacent icons by an equivalent un-bonded length. Such icons may be any desired design or shape, such as a heart, square, triangle, diamond, trapezoid, or circle. In FIG. **18**, the embossed icons are squares.

Implementations of the present invention can also include methods of forming multi-layered lightly-laminated film and bags including the same. FIGS. **26-28** and the accompanying description describe such methods. Of course, as a preliminary matter, one of ordinary skill in the art will recognize that the methods explained in detail herein can be modified. For example, various acts of the method described can be omitted or expanded, additional acts can be included, and the order of the various acts of the method described can be altered as desired.

FIG. **26** illustrates an exemplary embodiment of a high-speed manufacturing process **164** for creating multi-layered lightly-laminated thermoplastic film(s) and then producing multi-layered plastic bags therefrom. According to the process **164**, a first thermoplastic film layer **10***c* and a second thermoplastic film layer **10***d* are unwound from roll **165***a* and **165***b*, respectively, and directed along a machine direction.

The film layers **10***c*, **10***d* may pass between first and second cylindrical intermeshing rollers **166**, **167** to incrementally stretch and lightly laminate the initially separate film layers **10***c*, **10***d* to create un-bonded regions and bonded regions in at least one section of a multi-layered lightly-laminated film **168**. The intermeshing rollers **166**, **167** can have a construction similar to that of intermeshing rollers **12**, **14** of FIGS. **1**A-**1**B, or any of the other intermeshing rollers shown or described herein. The rollers **166**, **167** may be arranged so that their longitudinal axes are perpendicular to the machine direction. Additionally, the rollers **166**, **167** may rotate about their longitudinal axes in opposite rotational directions as described in conjunction with FIG. **1**A. In various embodiments, motors may be provided that power rotation of the rollers **166**, **167** in a controlled manner. As the film layers **10***c*, **10***d* pass between the first and second rollers **166**, **167**, the ridges and/or teeth of the intermeshing rollers **166**, **167** can form a multi-layered lightly-laminated film **168**.

During the manufacturing process **164**, the multi-layered lightly-laminated film **168** can also pass through a pair of pinch rollers **169**, **170**. The pinch rollers **169**, **170** can be appropriately arranged to grasp the multi-layered lightly-laminated film **168**.

A folding operation **171** can fold the multi-layered lightly-laminated film **168** to produce the sidewalls of the finished bag. The folding operation **171** can fold the multi-layered lightly-laminated film **168** in half along the transverse direction. In particular, the folding operation **171** can move a first edge **172** adjacent to the second edge **173**, thereby creating a folded edge **174**. The folding operation **171** thereby provides a first film half **175** and an adjacent second web half **176**. The overall width **177** of the second film half **176** can be half the width **177** of the pre-folded multi-layered lightly-laminated film **168**.

To produce the finished bag, the processing equipment may further process the folded multi-layered lightly-laminated film **168**. In particular, a draw tape operation **178** can insert a draw tape **179** into ends **172**, **173** of the multi-layered lightly-laminated film **168**. Furthermore, a sealing operation **180** can form the parallel side edges of the finished bag by forming heat seals **181** between adjacent portions of the folded multi-layered lightly-laminated film **168**. The heat seal **181** may strongly bond adjacent layers together in the location of the heat seal **181** so as to tightly seal the edges of the finished bag. The heat seals **181** may be spaced apart along the folded multi-layered lightly-laminated film **168** to provide the desired width to the finished bags. The sealing operation **180** can form the heat seals **181** using a heating device, such as, a heated knife.

A perforating operation **182** may form a perforation **183** in the heat seals **181** using a perforating device, such as, a perforating knife. The perforations **183** in conjunction with the folded outer edge **174** can define individual bags **184** that may be separated from the multi-layered lightly-laminated film **168**. A roll **185** can wind the multi-layered lightly-laminated film **168** embodying the finished bags **184** for packaging and distribution. For example, the roll **185** may be placed into a box or bag for sale to a customer.

In still further implementations, the folded multi-layered lightly-laminated film **168** may be cut into individual bags along the heat seals **181** by a cutting operation. In another implementation, the folded multi-layered lightly-laminated film **168** may be folded one or more times prior to the cutting operation. In yet another implementation, the side sealing operation **180** may be combined with the cutting and/or perforation operations **182**.

One will appreciate in light of the disclosure herein that the process **164** described in conjunction with FIG. **26** can be modified to omit or expand acts, vary the order of the various acts, or otherwise alter the process, as desired. For example, three or more separate film layers can be discontinuously laminated together to form a multi-layered lightly-laminated film **168** similar to that shown in FIG. **1**C.

FIG. **27** illustrates another manufacturing process **186** for producing a plastic bag from a multi-layered lightly-laminated film. The process **186** can be similar to process **164** of FIG. **26**, except that the film layers **10***c*, **10***d* are folded in half to form c-, u-, or j-folded films prior to winding on the rolls **165***a*, **165***b*. Thus, in such implementations, the films **10***c*, **10***d* unwound from the rolls **165***a*, **165***b* are already folded.

Additionally, the manufacturing process **186** illustrates that each film **10***c*, **10***d* can pass through a set of intermeshing rollers **166***a*, **167***a*, **166***b*, **166***b* to incrementally stretch the films prior to bonding. The manufacturing process **186** can then include an insertion operation **187** for inserting the folded film **10***d* into the folded film **10***c*. Insertion operation **187** can combine and adhesively laminate the folded films **10***c*, **10***d* using any of the apparatus and methods described in U.S. patent application Ser. No. 13/225,930 filed Sep. 6, 2011 and entitled Apparatus For Inserting A First Folded Film Within A Second Folded Film and Ser. No. 13/225,757 filed Sep. 6, 2011 and entitled Method For Inserting A First Folded Film Within A Second Folded Film, each of which are incorporated herein by reference in their entirety.



Additionally, FIG. **27** illustrates that the film layers **10***c*, **10***d* can then pass through a lamination operation **188** to lightly bond or laminate the films **10***c*, **10***d* together. Lamination operation **188** can lightly laminate the folded films **10***c*, **10***d* together via adhesive bonding, pressure bonding, ultrasonic bonding, corona lamination, and the like. Alternatively, lamination operation can lightly laminate the folded films **10***c*, **10***d* together by passing them through machine-direction ring rolls, transverse-direction ring rolls, diagonal-direction ring rolls, SELF'ing rollers, embossing rollers, or other intermeshing rollers.

FIG. **28** illustrates another manufacturing process **190** for producing a multi-layered lightly-laminated film and a multi-layered bag therefrom. The process **190** can be similar to process **164** of FIG. **25**, except that each film layer **10***c* and **10***d* may be run through intermeshing rollers (e.g., MD ring rollers) **166**, **167** and **166***a*, **167***a*, respectively, prior to discontinuous lamination of layers **10***c* and **10***d* to one another. Similar to process **164** of FIG. **25**, layers **10***c* and **10***d* may then be discontinuously laminated together by passing through intermeshing rollers **192**, **193**, which may be similar to rollers **153**, **154** of FIGS. **11**A-**11**B.

I. Examples

Multi-layered lightly-laminated films according to the present invention were formed according to various ring rolling processes. Table I below lists various discontinuously laminated films and comparative films that were tested. Table II lists the physical properties of the films of Table I. The results recorded in Table II indicate that the bi-layer films that were lightly bonded together with discontinuous lamination exhibit significantly improved strength properties, such as the energy to maximum load (Dynatup Max), which relates to impact resistance. The melt index of the layers of the films were determined under ASTM D-1238, Condition E. It is measured at 190° C. and 2.16 kilograms and reported as grams per 10 minutes.

TABLE I

Discontinuously Laminated Films

| Film | Layer 1 | Process | Layer 2 | Process | Discontinuous Lamination | Gauge (Mils) |
|---|---|---|---|---|---|---|
| A | LLDPE | | | | | 0.40 |
| B | LDPE | | | | | 0.40 |
| C | HDPE | | | | | 0.40 |
| D | LLDPE | | | | Yes | 0.40 |
| E | LDPE | | | | Yes | 0.40 |
| F | HDPE | | | | Yes | 0.40 |
| G | LLDPE | | LLDPE | | Yes | 0.80 |
| H | LDPE | | LDPE | | Yes | 0.80 |
| I | HDPE | | HDPE | | Yes | 0.80 |
| J | LLDPE | TD RR | LDPE | TD RR | Yes | 0.80 |
| K | LLDPE | TD RR | HDPE | TD RR | Yes | 0.80 |
| L | LDPE | TD RR | HDPE | TD RR | Yes | 0.80 |
| M | LLDPE | MD RR | LLDPE | TD RR | Yes | 0.80 |
| N | LLDPE | MD RR | LDPE | TD RR | Yes | 0.80 |
| O | LLDPE | MD RR | HDPE | TD RR | Yes | 0.80 |

LLDPE has a density of 0.920 and a Melt Index of 1.000. LDPE has a density of 0.926 and a Melt Index of 0.800. HDPE has a density of 0.959 and a Melt Index of 0.057. TD RR is TD ring rolling at 40 Pitch. MD RR is MD ring rolling at 60 Pitch. Discontinuous Lamination was achieved through SELF'ing at a DOE of 0.038".

TABLE II

| Physical Properties | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Tear | | Yield | | Peak Load | | Strain@Break | | DynatupEnergy |
| Film | MD | TD | MD | TD | MD | TD | MD | TD | to max. load |
| A | 165 | 274 | 0.66 | 0.64 | 3.44 | 1.59 | 532 | 606 | 3.10 |
| B | 72 | 283 | 0.81 | 0.86 | 3.72 | 2.28 | 482 | 660 | 0.25 |
| C | 3 | 314 | 1.74 | 0.86 | 3.83 | 0.89 | 268 | 135 | N.A. |
| D | 181 | 176 | 0.55 | 0.60 | 1.21 | 1.44 | 352 | 557 | 3.20 |
| E | 175 | 197 | 0.70 | 0.75 | 1.46 | 1.21 | 331 | 473 | 1.71 |
| F | 12 | 170 | 0.30 | 3.13 | 1.70 | 0.70 | 115 | 64 | 0.45 |
| G | 372 | 427 | 1.12 | 1.25 | 2.92 | 2.59 | 389 | 551 | 5.81 |
| H | 312 | 375 | 1.39 | 1.54 | 2.83 | 2.39 | 346 | 518 | 3.60 |
| I | 14 | 220 | 1.20 | 0.44 | 2.71 | 1.07 | 112 | 78 | 0.87 |
| J | 392 | 385 | 1.21 | 1.40 | 3.19 | 2.71 | 385 | 540 | 4.15 |
| K | 191 | 292 | 1.75 | 1.27 | 2.62 | 1.53 | 61 | 535 | 3.32 |
| L | 158 | 288 | 2.20 | 1.50 | 3.00 | 1.55 | 252 | 498 | 2.63 |
| M | 539 | 368 | 1.26 | 1.26 | 3.32 | 3.06 | 456 | 401 | 7.19 |
| N | 544 | 383 | 1.27 | 1.69 | 2.18 | 2.91 | 365 | 362 | 6.96 |
| O | 574 | 189 | 1.44 | 3.87 | 1.74 | 3.87 | 404 | 157 | 1.41 |
| Control | 225 | 625 | 1.46 | 1.43 | 6.29 | 4.36 | 476 | 665 | |

Tear in grams.
Yieldin $Lb_f$
Peak Load in $Lb_f$
Strain@Break in %
Dynatup Energy to Max in In-$Lb_f$
Control is 0.9 Mil LDPE film

As shown in Table III, another set of films was evaluated with different levels of stretch processes with and without discontinuous lamination of adjacent layers. The results show significantly increased values of Dynatup Energy to maximum load as a result of discontinuous lamination.

TABLE III

| Additional Examples | | | | | | |
|---|---|---|---|---|---|---|
| Film | Layer 1 Process | Layer 2 Process | Discontinuous Lamination | Dynatup Energy to max. load | Gauge Initial (mils) | Gauge Final (mils) |
| P | None | None | Yes | 18.3 | 2.14 | 2.12 |
| Q | MD-1 | TD-1 | No | 7.2 | 2.14 | 1.92 |
| R | MD-1 | TD-1 | Yes | 17.1 | 2.14 | 1.93 |
| S | MD-2 | TD-2 | No | 8.7 | 2.14 | 1.68 |
| T | MD-2 | TD-2 | Yes | 15.3 | 2.14 | 1.63 |
| Base | None | None | No | 5 | 1.07 | 1.07 |

As shown in Table IV, samples of cold processed MD ring rolled (at 0.100" DOE, 0.100" pitch, LDPE film were laminated under a cold ring rolling process to achieve unexpectedly superior tear resistance properties. The MD Tear and the TD Tear resistance values were synergistically enhanced as a result of the discontinuous lamination process. Bond strength could be further increased while still being less than the strength of the weakest layer by addition of a tackifier, an adhesive, corona treatment, etc. to increase tackiness between the layers.

TABLE IV

| Ring Rolled Laminates | | |
|---|---|---|
| Sample | MD Tear | TD Tear |
| TD ring rolled laminate of A and B, 21.5 gsm[a] | 429 | 881 |
| A. MD ring rolled, Black top layer[b] | 193 | 580 |
| B. MD ring rolled, White bottom layer[c] | 261 | 603 |
| TD ring rolled laminate of C and D, 18.8 gsm | 314 | 876 |
| C. MD ring rolled, Black top layer[d] | 170 | 392 |

TABLE IV-continued

| Ring Rolled Laminates | | |
|---|---|---|
| Sample | MD Tear | TD Tear |
| D. MD ring rolled, Black bottom layer[d] | 151 | 470 |
| TD ring rolled laminate of E and F, 21.1 gsm | 312 | 1018 |
| E. MD ring rolled, Black top layer[b] | 218 | 765 |
| F. MD ring rolled, Black bottom layer[d] | 170 | 387 |

[a]TD ring rolling was 0.040" pitch tooling run at 0.020" DOE. The A and B webs were simultaneously run first through the MD and then the TD tooling.

[b]14 gsm 3 ply coextruded black layer with outer skin plies containing 30% DOW Affinity ™ 8100 and 2% talc, processed at blowup ratio A and MD ring rolled. MD ring rolling was 0.100" pitch tooling run at 0.100" DOE.

[c]14 gsm 3ply coextruded white layer with 2% slip agent in outer skin plies, processed at blowup ratio 1.5A and MD ring rolled at 0.100" pitch tooling run at 0.100" DOE.

[d]14 gsm 3 ply coextruded black layer with outer skin plies containing 30% DOW Affinity ™ 8100 and 2% talc, processed at blowup ratio 1.5A and MD ring rolled at 0.100" pitch tooling run at 0.100" DOE.

The MD and TD tear values shown in Table IV show how the MD tear value is significantly increased relative to the MD tear value of the individual layers. The data shows an additive or synergistic effect in both MD and TD tear resistance. For example, Example A exhibits an MD tear resistance of 193 g-f, while Example B exhibits an MD tear resistance of 261 g-f. When both layers are lightly laminated together by TD ring rolling, the MD tear resistance is 429 g-f. This is nearly as great as the additive strength of the two layers, which would be 454 g-f. Such results are particularly surprising and advantageous, as when the two layers are tightly laminated together (e.g., co-extruded), the strength of the composite film typically reverts to the have a strength approximately equal to that of the weakest layer (i.e., about 193 g-f). Thus, the light, discontinuous lamination of adjacent layers into a multi-layer film provides significant increases in strength.

Examples A through F were each discontinuously laminated by MD ring rolling at a pitch of 0.100", a DOE of 0.100", and simultaneously TD ring rolling at a pitch of 0.040" and a DOE of 0.020".

In another example, a first layer of a base film having a core ply of LLDPE with white pigment and outer plies of LLDPE\LDPE\Antiblock blend was cold MD ring rolled to form an MD ring rolled (RR) film. The MD intermeshing rolls used in Example 1 had a 0.100" pitch and were set at a DOE of 0.110". A second layer of the base film was cold TD ring rolled to form a TD RR film. The TD intermeshing rolls used in Example 1 had a 0.060" pitch and were set at a DOE of 0.032". The MD RR film and the TD RR film were then laminated together using a butene-1-copolymer, hot melt adhesive, Rextac® RT 2730 at four different coat weights shown in Table V as samples 1-4. Table V also shows comparative properties of the base film, the MD RR film, the TD RR film, the combined MD RR and TD RR films not adhesively laminated together, as well as a thicker film.

TABLE V

Dynatup and Tear Resistance of Incrementally-Stretched Adhesively-Laminated Films (1 layer MD RR and 1 layer TD RR)

| | Coat Weight g/sq. ft. | Gage by Wt. (mils) | Tensile Peel (g-f) | Dynatup Peak Load (lb-f) | Dynatup Energy to max load (in. lb-f) | MD Tear (g) | TD Tear (g) |
|---|---|---|---|---|---|---|---|
| Sample 1 | 0.225 | 0.84 | N/A | 11.3 | 8.4 | 434 | 585 |
| Sample 2 | 0.056 | 0.84 | N/A | 11.1 | 11.2 | 496 | 539 |
| Sample 3 | 0.015 | 0.84 | 61 | 10.5 | 9.2 | 387 | 595 |
| Sample 4 | 0.012 | 0.84 | 57 | 11.3 | 10.4 | 425 | 643 |
| Comparison Data | | | | | | | |
| Un-laminated Combined MD and TD RR Films | NA | 0.84 | N/A | 9.4 | 6.9 | 326 | 502 |
| TD RR Film | NA | 0.4 | N/A | 4.6 | 4.4 | 101 | 60 |
| MD RR Film | NA | 0.44 | N/A | 5.4 | 4.8 | 173 | 475 |
| Base Film | NA | 0.6 | N/A | 5.1 | 6.3 | 298 | 473 |
| Thicker Base Film | NA | 0.9 | NA | 4.3 | 3.8 | 262 | 843 |

The results from Table V show that even with very low adhesive coating, superior Dynatup, MD tear resistance, and TD tear resistance properties are achieved compared to two layers of non-laminated film or one layer of thicker film. In particular, the results from Table V show adhesively laminating an MD RR film and a TD RR film can balance the MD and TD tear resistance. Furthermore, the individual values for the Dynatup, MD tear resistance, and TD tear resistance properties are unexpectedly higher than the sum of the individual layers. Thus, the incrementally-stretched adhesively-laminated films provide a synergistic effect.

More specifically, as shown by the results from Table V, the TD tear resistance of the incrementally-stretched adhesively-laminated films can be greater than a sum of the TD tear resistance of the individual layers. Similarly, the MD tear resistance of the incrementally-stretched adhesively-laminated films can be greater than a sum of the MD tear resistance of the individual layers. Along related lines, the Dynatup peak load of the incrementally-stretched adhesively-laminated films can be greater than a sum of a Dynatup peak load of the individual layers.

TABLE VI

Properties of Incrementally-Stretched Adhesively-Laminated Films (both layers MD and TD RR)

| | Coat Wt. g/sq. ft. | Gage by Wt. (mils) | Caliper 1" Foot (mils) | Tensile Peel (g-f) | Dynatup Peak Load (lb-f) | Dynatup Energy to max load (in. lb-f) | Dart Drop F50 (g) | MD Tear (g) | TD Tear (g) |
|---|---|---|---|---|---|---|---|---|---|
| Sample 5 | 0.0300 | 0.64 | 1.71 | 81.5 | 11.5 | 11.28 | 254.0 | 418 | 511 |
| Sample 6 | 0.0150 | 0.65 | 1.85 | 25.5 | 10.3 | 9.61 | | 349 | 441 |
| Sample 7 | 0.0100 | 0.67 | 1.81 | 27.6 | 10.6 | 9.34 | 264.0 | 353 | 406 |
| Sample 8 | 0.0075 | 0.66 | 1.79 | 2.27 | 9.7 | 10.99 | | 335 | 423 |
| Sample 9 | 0.0060 | 0.66 | 1.87 | 7.79 | 9.9 | 12.21 | 260.0 | 319 | 450 |
| Comparison Data | | | | | | | | | |
| Thicker Base Film | NA | 0.9 | 0.88 | NA | 4.3 | 3.8 | 180 | 262 | 843 |

The results from Tables VI show that even with very low adhesive coating, superior Dynatup, MD tear resistance, and TD tear resistance properties are achieved compared to two layers of non-laminated film or one layer of thicker film. Additionally, the results from Tables VI in conjunction with the Comparison Data from Table V show that incrementally-stretched adhesively-laminated films of one or more implementations can allow for a reduction in basis weight (gauge by weight) as much as 50% and still provide enhanced strength parameters.

In addition to allowing for films with less raw material yet enhanced strength parameters, the results from Table VI further shows that incrementally-stretched adhesively-laminated films of one or more implementations can have an increased gauge (i.e., caliper) despite the reduction in basis weight. Some consumers may associate thinner films with decreased strength. Indeed, such consumers may feel that they are receiving less value for their money when purchasing thermoplastic film products with smaller gauges. One will appreciate in light of the disclosure herein that despite a reduction in raw material, incrementally-stretched adhesively-laminated films of one or more implementations may be and look thicker than a single layer of film with a higher basis weight. Thus, one or more implementations can enhance the look and feel of a film in addition to enhancing the strength parameters of the film.

In an additional example, one white layer of HDPE with a low MD tear resistance was cold stretched by MD ring rolling at 0.110 DOE. Another black layer of LLDPE was cold stretched by MD ring rolling at 0.110 DOE followed by TD ring rolling at 0.032 DOE and then laminated together with the same adhesive. Again, with the two ply laminates superior properties were obtained even at very low adhesive levels compared to a single ply film as shown by the results of Table VII.

TABLE VII

Dynatup and Tear Resistance of Incrementally-Stretched Adhesively-Laminated Films (1 layer MD RR and 1 layer MD and TD RR)

| | Coat Wt. g/sq. ft. | Gage by Wt. (mils) | Dynatup Peak Load (lb-f) | Dynatup Energy to max load (in. lb-f) | Dart Drop F50 (g) | MD Tear (g) | TD Tear (g) |
|---|---|---|---|---|---|---|---|
| Sample 10 | 0.0300 | 0.67 | 11.83 | 11.86 | 284 | 357 | 575 |
| Sample 11 | 0.0150 | 0.67 | 11.79 | 14.21 | | 357 | 532 |
| Sample 12 | 0.0100 | 0.67 | 10.99 | 10.77 | 288 | 373 | 502 |
| Sample 13 | 0.0075 | 0.67 | 11.80 | 11.60 | | 360 | 530 |
| Sample 14 | 0.0060 | 0.67 | 12.60 | 10.57 | 260 | 385 | 535 |
| Comparison Data | | | | | | | |
| Thicker Base Film | NA | 0.9 | 4.3 | 3.8 | 180 | 262 | 843 |

In a final example, a bag formed from an incrementally-stretched adhesively-laminated film were compared to single ply bags of heavier basis weight using a consumer test with 17 lbs. of mixed garbage on an end use scale of 1-5. The laminate of two layers which were independently MD ring rolled and then TD ring rolled followed by adhesive lamination has an excellent score comparable to single layer bags of higher basis weight.

TABLE VIII

End Use Testing

| Sample | Gage by Wt. (mils) | End use score |
|---|---|---|
| Incrementally-Stretched Adhesively-Laminated | 0.66 | 4.16 |
| MD ring rolled single layer | 0.80 | 4.08 |
| Strainable network single layer | 0.85 | 4.50 |

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. Thus, the described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

We claim:

**1**. A method for forming a thermoplastic bag with a bag-in-bag configuration, the method comprising:
- providing first and second thermoplastic films;
- incrementally-stretching the first and second thermoplastic films to define a plurality of alternating stretched and un-stretched regions in each of the first and second thermoplastic films;
- non-continuously laminating the first thermoplastic film to the second thermoplastic film by a process selected from the group consisting of adhesive bonding, ultrasonic bonding, embossing, ring rolling, selfing, and combinations thereof by forming a plurality of non-continuous bonded regions that extend in a direction that is either parallel to a direction of extrusion of the first and second thermoplastic films or perpendicular to the direction of extrusion of the first and second thermoplastic films, wherein the plurality of non-continuous bonded regions are aligned with and bond the un-stretched regions of the first and second thermoplastic films together; and
- joining at least two edges of the first thermoplastic film and the second thermoplastic film together to form a bag configuration.

**2**. The method as recited in claim **1**, further comprising folding non-continuously laminated first and second thermoplastic films prior to joining.

**3**. The method as recited in claim **2**, further comprising cold incrementally stretching one or more of the first thermoplastic film and the second thermoplastic film prior to non-continuously laminating the first thermoplastic film to the second thermoplastic film to form an incrementally-stretched non-continuously multi-layer laminated film.

**4**. The method as recited in claim **3**, wherein the incrementally-stretched noncontinuously multi-layer laminated film has a basis weight less than a combined basis weight of the first and second thermoplastic films prior to cold incrementally stretching one or more of the first thermoplastic film and the second thermoplastic film.

**5**. The method as recited in claim **1**, wherein incrementally-stretching is a cold stretching.

**6**. The method of claim **1**, further comprising forming the plurality of non-continuous bonded regions such that the thermoplastic bag has a tear resistance greater than either a tear resistance of the first thermoplastic film or a tear resistance of the second thermoplastic film.

**7**. The method of claim **6**, further comprising forming the plurality of non-continuous bonded regions such that the tear resistance of the thermoplastic bag is greater than a sum of the tear resistance of the first thermoplastic film and the tear resistance of the second thermoplastic film.

**8**. The method of claim **1**, further comprising forming the plurality of non-continuous bonded regions such that the bonded regions have a bond strength less than a weakest tear resistance of either the first or second thermoplastic films.

**9**. A method of forming a thermoplastic bag with a bag-in-bag configuration, the method comprising:

stretching a first continuous layer of thermoplastic film to form, in the first continuous layer, one of:

a plurality of alternating stretched and un-stretched increments extending perpendicular to a machine direction of the first continuous layer of thermoplastic film,

a plurality of alternating stretched and un-stretched increments extending parallel to the machine direction of the first continuous layer of thermoplastic film, or

a plurality of rib like elements in a discontinuous strainable network, the rib-like element comprising stretched and un-stretched increments;

stretching a second continuous layer of thermoplastic film to form, in the second continuous layer, another of:

a plurality of alternating stretched and un-stretched increments extending perpendicular to a machine direction of the first continuous layer of thermoplastic film,

a plurality of alternating stretched and un-stretched increments extending parallel to the machine direction of the first continuous layer of thermoplastic film, or

a plurality of rib like elements in the discontinuous strainable network, the rib-like element comprising stretched and un-stretched increments; and

bonding the first continuous layer to the second continuous layer by forming a plurality of bonds directly between the un-stretched increments of the first continuous layer and the un-stretched increments of the second continuous layer by a process selected from the group consisting of adhesive bonding, ultrasonic bonding, embossing, ring rolling, strainable network formation, and combinations thereof;

wherein the machine direction of the first continuous layer of thermoplastic film is parallel to a machine direction of the second continuous layer of thermoplastic film; and

forming the bonded first and second continuous layers into a bag.

**10**. The method of claim **9**, wherein:

stretching the first continuous layer of thermoplastic film comprises forming, in the first continuous layer, the plurality of alternating stretched and un-stretched increments extending perpendicular to the machine direction of the first continuous layer of thermoplastic film; and

stretching the second continuous layer of thermoplastic film comprises forming, in the second continuous layer, the plurality of alternating stretched and un-stretched increments extending parallel to the machine direction of the first continuous layer of thermoplastic film.

**11**. The method of claim **10**, wherein bonding the first continuous layer to the second continuous layer by forming the plurality of bonds comprises forming partially discontinuous bonds aligned with the plurality of alternating stretched and un-stretched increments extending parallel to the machine direction of the first continuous layer of thermoplastic film.

**12**. The method of claim **9**, wherein stretching the second continuous layer of thermoplastic film comprises forming, in the second continuous layer, the plurality of rib like elements in the discontinuous strainable network.

**13**. The method of claim **12**, wherein bonding the first continuous layer to the second continuous layer by forming a plurality of bonds directly between the first continuous layer and the second continuous layer comprises forming discontinuous bonds aligned with the rib like elements in the discontinuous strainable network.

**14**. The method of claim **9**, wherein forming the bonded first and second continuous layers into a bag comprises forming the bonded first continuous layer to the second continuous layer into a trash bag with a draw string.

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